THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR CRAIG P. ACOTT

TITLE OF THESIS COAL VALLEY PIT SLOPE STABILITY STUDY: EVALUATION OF CONE INDENTER AND BRUSH PLATENS AND JANBU/MORGENSTERN-PRICE ANALYSES

DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED FALL 1981

THE UNIVERSITY OF ALBERTA

COAL VALLEY PIT SLOPE STABILITY STUDY: EVALUATION OF CONE INDENTER AND BRUSH PLATENS AND JANBU/MORGENSTERN-PRICE ANALYSES

by

© CRAIG P. ACOTT

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

MINING ENGINEERING

DEPARTMENT OF MINERAL ENGINEERING

EDMONTON, ALBERTA

FALL 1981

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled COAL VALLEY PIT SLOPE STABILITY STUDY: EVALUATION OF CONE INDENTER AND BRUSH PLATEN TESTS AND JANBU/MORGENSTERN-PRICE ANALYSES submitted by CRAIG P. ACOTT in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in MINING ENGINEERING.

Abstract

As partial fulfilment of the requirements for a M.Sc. Degree in Mining Engineering, a slope stability analysis and rock testing program was conducted on Luscar Sterco (1977) Ltd.'s Coal Valley Property. The analysis was completed using two different limit equilibrium models, namely the Morgenstern-Price and Simplified Janbu Method. The same geotechnical/geological data base was applied to each method in order to evaluate the application of Janbu's simplified model to slope stability analysis for mine slope design at Coal Valley.

An additional objective of this study was to evaluate the National Coal Board's (NCB) Cone Indenter as a quick index test for determining the uniaxial compressive strength of the soft rocks characteristic of Coal Valley strata. Test results from the Cone Indenter were compared to uniaxial compression tests conducted on similar specimens. A third goal of the research was the construction and preliminary testing of brush platens which, if successful, will permit uniaxial compressive strength testing of cylindrical specimens with unit length to diameter ratios less than the standard 2:1 value.

Results of the limit equilibrium analyses indicated that the additional expense of the Morgenstern-Price method can not be justified for slope design at Coal Valley. It was also found from the limited number of tests obtained with the NCB Cone Indenter and brush platens, that uniaxial

compressive strength values correlated reasonably well with those obtained by conventional testing methods. Additionally, the NCB Cone Indenter provides a useful index test for a variety of other mining applications, such as rock cuttability, drillability, and blastability indexing.

Acknowledgments

I would like to extend my gratitude to those people who assisted me over the course of this study. Special thanks are extended to Dr. B. Stimpson for his very valuable assistance and advice during this project.

I would also like to acknowledge the help provided by my fellow students: H. Lutley and R. Wright. In addition, thanks are extended to L. Ding and M. Gendron for their valuable technical assistance.

Finally, I would like to thank Luscar Ltd. for permitting the study to be conducted, and for the use of their computer system, library, and office services. In particular, I would like to acknowledge the assistance provided by the entire Geotechnical Department, consisting of M. Milligan, K. Hebil, and K. Holmes.

Table of Contents

List of Tables

List of Figures

List of Photos

1. Introduction

Mining of Pit 13 at the Coal Valley mine is tentatively scheduled for summer 1983. Past experience of Luscar Sterco (1977) Ltd. in Coal Valley has revealed that the pit wall stability is largely dependent upon the structural geology. Due to local variations in the geology over relatively short distances, it is not possible to predict the pit wall stability of Pit 13 entirely upon geotechnical information gathered from previously mined pits in the same area. Consequently, it was thought that a separate stability analysis was required for Pit 13.

Work began on the analysis in May 1979. Preliminary investigation of the area involved the collection and compilation of the existing geological information pertaining to the project. A preliminary geological interpretation for the Pit 13 area was developed based upon aerial photo interpretation, geophysical log interpretation, and drillhole log correlation.

After completion of the tentative geologic interpretation, a drilling and mapping program was initiated and completed. The field program was directed towards further delineation of geological structure and the provision of rock samples for a laboratory testing program. The testing program was designed to provide values of each major lithological unit's intact strength properties and to provide a basis on which the rock mass strength parameters could be estimated. The laboratory program was augmented

with quantitative strength estimates derived from back analyses of slope failures in previously mined areas in similar lithologies.

The geologic structure and strength parameters of the Pit 13 wall rock were used as a data base for two different limit equilibrium stability models, the Simplified Janbu and Morgenstern-Price. The overall factors of safety determined from these two slope stability methods were compared and their ease of application, accuracy, and cost contrasted.

2. Site Description

2.1 Location

The Coal Valley thermal coal mine is situated on the eastern edge of the Foothills of the Rocky Mountains, some 85 kilometers (52 miles) south of Edson, Alberta (Figure 1), and comprises four major mining zones: the Val D'Or, Silkstone, Mynheer A, and Mynheer B (Figure 2).

For the purposes of this study, work was limited to the proposed Pit 13 area located in the central portion of the Mynheer A mining region. The pit is bounded by the local grid lines 76200E to 80000E and 37000N to 41000N.

2.2 Surficial Aspects

2.2.1 Topography

The topographic relief is the most prominant surficial feature in the Pit 13 area (Photo 1). The mining zone is located on the south slope of a northwest striking ridge. The peak elevation of the ridge is approximately 1460 m (4800 ft), dipping to the southwest at an angle of about 25 degrees. Situated at the proposed mining site are two old surface mines. The bottom elevation of the old mines is roughly 1370 m (4500 ft), giving an overall topographic relief of about 90 m (300 ft). A more detailed description of these mines is given in Sections 2.6 and 2.8.

COAL VALLEY LOCATION MAP

FIGURE 1

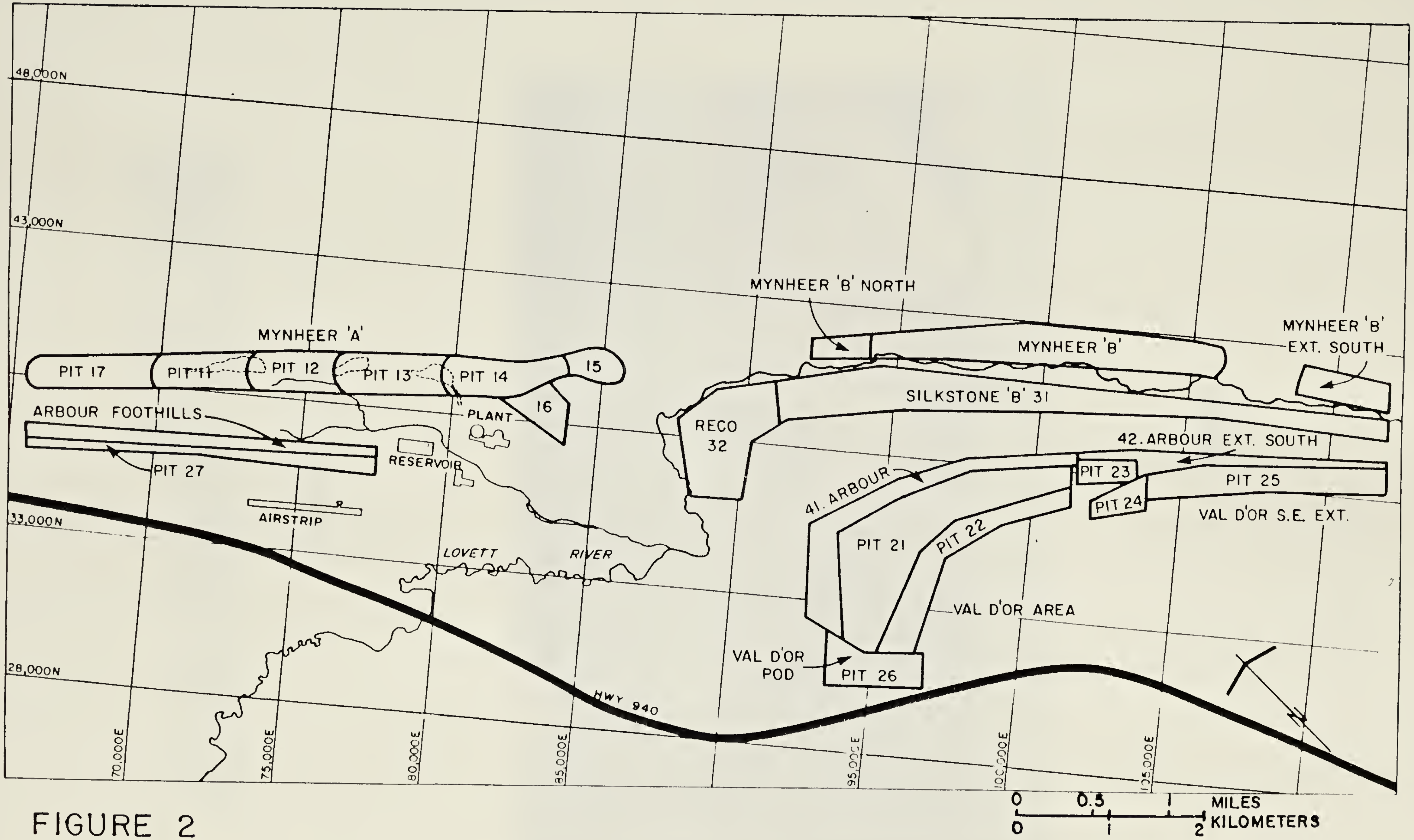


FIGURE 2

COAL VALLEY PIT LOCATIONS

PHOTO 1

PIT 13 AREA

Photo facing north, illustrating the central ridge in background, water filled old mine workings in foreground. Note condition of lower slopes excavated 25 to 30 years ago.

2.2.2 Soils

The soils in the Coal Valley region have been considerably disturbed by the early open pit and underground mining operations. The natural soil profile has been excavated or covered with fill in several areas of Pit 13. The original soils are generally classified as degraded Eutric Brunisols of the Maskuta Association (Dumanski et. al. 1972). They are sandy and well drained, characteristic of the calcareous sandstone from which they originated. The soils are shallow near the crest of the ridge but have been transported downslope to form deeper colluvial deposits near the toe. The exact thickness of the soils is somewhat variable, but generally ranges from 1 m (3 ft) near the ridge to 3 m (10 ft) at the bottom.

2.2.3 Vegetation

Floral composition of the Pit 13 area is dictated by the relatively dry conditions and the sandy, well drained soils. Slopes of 20 to 25 degrees on the southwest facing ridge retain little moisture, resulting in the development of a lodgepole pine - aspen poplar association. Understory vegetation consists of wild rose, creeping juniper, and bearberry, with interspersed grasses and forbs (Acott 1981).

2.3 Climate

The Coal Valley area generally experiences a subhumid, continental climate with long, cold winters and moderately mild summers. Winds are predominantly from the west and are most prominant in the months of March through June. Chinook winds are common in the winter months (Hillman et. al. 1978).

Precipitation data from the Lovett Fire Tower indicate an average annual precipitation of approximately 64 cm (25 in). The mean long term average for the months of May through September is 47 cm (18.5 in). The largest amounts of precipitation occurs in June and July (Environment Canada 1975).

Temperatures in the Coal Valley region have a high seasonal variation. The highest monthly mean temperature occurs in July and averages 13.3°C. The lowest monthly mean temperature is -18.3°C and occurs in January (Environment Canada 1975).

2.4 General Geology of the Coal Valley Area

The Coal Valley mining area occurs in a region of shallow, northeast striking thrust faults. It lies between the southerly dipping (60-80°) Beaverdam Thrust to the southwest and the easterly dipping Lovett Thrust to the northeast. Also located in the Coal Valley area is a series of steeply dipping to vertical northeast striking faults,

namely the Reco Fault and Reco Fault Extension (Internal Luscar Ltd. Report, 1978).

The Lovett River Syncline is the major fold in the region. It is located southwest of the mining area, and trends at approximately 135° plunging 5° to the south. This structure extends as far south as the Beaverdam Thrust (Alexander, 1977) and is offset by the Reco Fault. The Coal Valley Mine is located on the northern limb of the Lovett River Syncline whose beds dip at 15 to 18 degrees to the southwest.

2.5 Stratigraphy

The strata encountered in the Coal Valley area are generally referred to as the Coalspur Coal Measures (Alexander, 1977) and are part of the thick post-Wapiabi non-marine sediments of the Saunders Formation. The exact age of the Coalspur Coal Measures is unsure but considered by Alexander (1977) to be Paleocene in age. The coal measures consist of a monotonous sequence of arenaceous and argillaceous strata with few marker beds and fossils. Consequently, their exact stratigraphy and total thickness have not been determined (Internal Luscar Ltd. Report, 1978).

2.6 History

The eastern end of Pit 13 was previously mined by Coal Valley Mining Ltd.. The extraction method is uncertain, but consisted either of a truck-shovel or dragline operation. The company later joined with Sterling Collieries Ltd. and mined the western end of Pit 13 in a similar fashion. A central ridge, some 245 m (800 ft) long and 90 m (300 ft) high, resulted from the two operations. The Sterling Coal Valley mine remained in operation until 1954.

In July 1978, Luscar Sterco Ltd. developed a 2.27 million tonne (2.5 million ton), clean coal surface operation on the Coal Valley site. The surface Mine presently comprises a stripping operation in the Val D'Or region with open pit mining in the Mynheer A region. At this time, Pits 14 and 15 are the only areas being mined in the Mynheer A zone.

2.7 Mining Methods

The mining method for Pit 13 will be similar to that used in the Pit 14 area (Photo 2). Rock will be excavated using a truck-shovel operation. The rock is blasted and generally removed one bench at a time. Previous mining by Luscar Sterco (1977) Ltd. in the Mynheer A region has involved 10 m (33 foot) bench heights at approximately 60 degree to 65 degree face angles. The overall slope angle in the Pit 14 overburden will be 33 degrees.

PHOTO 2

PIT 14 NORTH WALL

North wall excavated in sandstones, siltstones, and interbedded mudstones at overall angle of approximately 33°. Loading equipment working on top of coal pod. Slope has subsequently failed about 1 year after photo was taken.

The truck-shovel operation removes rock to the top of the coal, while the coal will be primarily excavated by a Marion 7450 walking dragline (Photo 3). The dragline has a 61 m (200 ft) boom and 10.7 m^3 (14 yd^3) coal bucket. The dragline will be located on top of the coal, which will not have to be blasted prior to excavation. The coal is either stockpiled and loaded by a front end loader or placed directly into the trucks by the dragline. The coal is extracted by the dragline located on a bench on top of the coal, therefore, no safety benches are required in the coal cut. Excavation of the coal face will be steepened to 55°. The overall slope of the ultimate pit wall is variable depending on the thickness of the coal, but generally ranges from 35 to 38 degrees. Maximum wall heights over the 1160 m (3800 ft) long pit vary between 90 to 107 meters (300 to 500 ft). The average width of the proposed Pit 13 is approximately 365 m (1200 ft).

The extraction method has several geotechnical implications, including slope geometry and life span of the pit excavation. Because the dragline will mine the coal in one pass, the time required for any one area of the pit to remain open will be minimized. The slope geometry will be such that the steeper excavation will be in the lower portion of the slope. This is favourable since no men or equipment will be operating below the steeper section of the wall. Bench scale failures may result from the overburden blasting, however, the overall mining approach is generally

PHOTO 3

MARION 7450 WALKING DRAGLINE

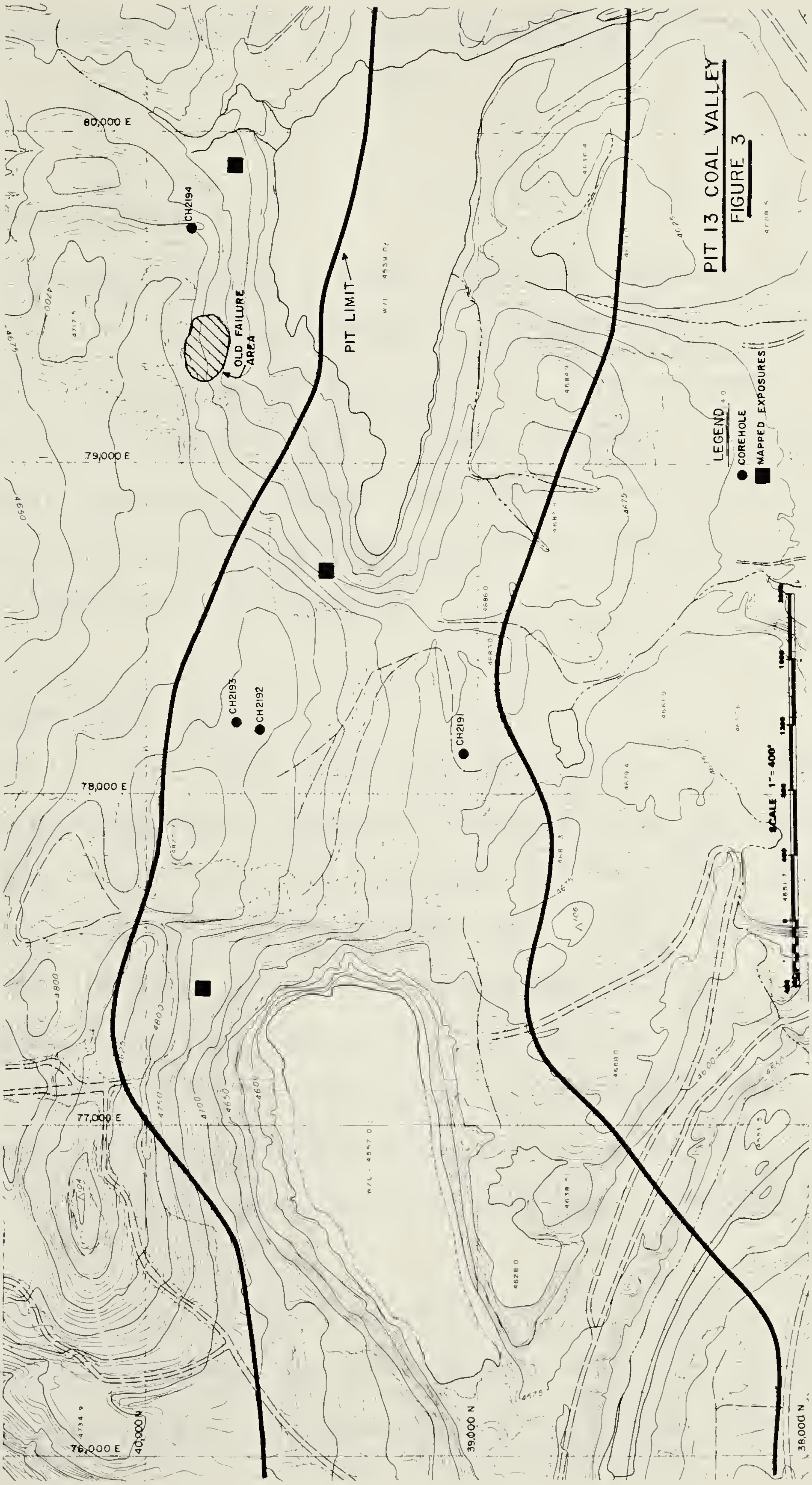
Pit 13 area in background.

favourable from a geotechnical viewpoint.

2.8 Slope Stability in Earlier Mining Operations

Although very little is known about the previous mining activities in the Pit 13 area, some information can be gained from the remnant workings. Recent drilling has revealed a small failure near Section 78400E on the north wall of the old workings (Figure 3). It appears that it is a transition zone between the fairly steep wall to the west (31°) and the shallower cut to the east (20°). The present walls of the old mine operations appear to be fairly stable, however, weathering has reduced the exterior faces of the walls to a soil-like mass. Very shallow circular failures have occurred in the soil material, especially in the west end of the Pit 13 area.

Backfilling of the old pits and the collection of water has concealed much of the geotechnical information which could have been obtained from the previous workings. The water and fill material make drilling conditions and geological mapping very difficult, obscuring the exact outline of the old pit walls.



PIT 13 COAL VALLEY
FIGURE 3

3. Site Investigation and Detailed Geology of the Pit 13 Area

3.1 Field Program

In preparation for a slope stability analysis of the walls of Pit 13 in the Mynheer A area, a fairly extensive geological study was carried out over the proposed site. Since the north wall of Pit 13 was suspected, on the basis of overall geologic structure and face orientation, to be potentially the most unstable, most of the investigation was concentrated over that area.

3.1.1 Sources of Data

Drill logs from existing drill holes as well as borehole geophysical logs were interpreted to provide the best estimate of the local geology. This data was augmented with information obtained from the 1979 Geotechnical Drilling Program, which consisted of four vertical coreholes, totalling 450 m (1475 ft), drilled in June and July of 1979 (Table 1). Geological information of Pit 13 was also derived from a field mapping program conducted on the walls of the old mine workings and other exposures in the area.

As stated earlier in Section 2.8, most of the old surface mine workings have filled with water or have been used as waste dumps. Consequently, the depth of fill and the

location of the old pit boundaries were determined or inferred from either the Kenting Exploration Services Ltd. Pit Bottom Survey conducted in 1977 or from sections and topographic maps of the Sterling-Coal Valley Mine.

3.1.2 Corehole Program

During a two week period, from June 23 through July 8 1979, four geotechnical coreholes were completed in the Mynheer A Pit 13 area (Figure 3). The coreholes were numbered successively from 2191 through 2194. Their location and total depth is given in Table 1.

On-site drilling supervision was provided to monitor drill hole water levels, to collect rock samples, and to box the core which was subsequently taken to a temporary core shack where it was geologically logged and photographed. Bore hole logs and Geolograph records (recording drilling rates) were compiled for each hole. Geophysical logs, including Single Point Resistivity, Focussed Gamma-Gamma Density, Natural Gamma, and Motorized Arm Caliper were run immediately upon completion of each hole.

Coreholes (CH) 2191, 2192, and 2193 were drilled to a depth of 17 m (55 ft) using mud and a 22 cm (8-3/4 in) rotary bit. CH2194 was drilled in the same manner to a depth of 11.5 m (38 ft). After drilling with the large bit, a 20 cm (8 in) steel casing was installed before coring began.

CH2191 was cored to 40 m (130 ft) with a 14.3 cm (5-5/8 in) carbide insert bit and an air-water mixture for drilling

----

TABLE 1

GEOTECHNICAL COREHOLE PROGRAM

Corehole Number	Location Northing	Location Easting	Elevation m	Elevation ft	Total Depth m	Total Depth ft	Attitude
2191	39037	78129	1422	4664	116	380	Vertical
2192	39659	78189	1458	4784	120	393	Vertical
2193	39821	78218	1454	4771	108	354	Vertical
2194	39865	79700	1425	4676	106	348	Vertical

----

fluid. At this depth the bit was replaced by an annular discharge diamond bit. At a depth of 70 m (223 ft), mud was used for drilling fluid in order to improve circulation.

CH2192 was cored to a depth of 48 m (157 ft) using an air-water drilling fluid and the carbide insert bit. At this point the diamond bit was installed and the hole was completed.

CH2193 was cored entirely with air-water and the carbide bit.

CH2194 was cored to 23 m (74 ft) using air-water and the carbide bit, then completed with the diamond bit.

3.1.3 Drilling Rig and Core Barrel

The coring rig used for the geotechnical coring program was a Failing 1250 mounted on a 9000 Ford diesel truck. It was equipped with an air-water injector system with a 650 cfm, 250 psi compressor.

The core barrel was a 3 m (10 ft) Christiansen, triple tube consisting of an outer core barrel with a back end latching system. A 3 m (10 ft) length of 7.6 cm (3 in) Poly Vinyl Chloride (PVC) tubing was inserted into the inner barrel so that upon completion of a core run, the core could be removed intact encased in the plastic tubing. Each core run was usually kept to a maximum of 2.75 m (9 ft), to allow for axial swelling of the core.

3.1.4 Geophysical Logging

The Geophysical Logging System was built for Lexco Testing Ltd. by Canadian Arctic Survey Systems using components produced by Comprobe Inc.. The receivers, recorder, and winch are contained in a 1.5 m (5 ft) by 2.75 m (9 ft) steel-framed shed which can be mounted on either a CF-60 tracked vehicle or a four wheel drive vehicle.

The logs produced include a Natural Gamma, Focussed Gamma-Gamma Density, Single-Point Resistance and a Motorized Arm Caliper. The downhole tool is 5.4 cm (2-1/8 in) in diameter by 2.75 m (9 ft) long. A four conductor cable allows all four logs to be run simultaneously.

Although each geophysical log would produce only limited results if used separately, they become extremely useful for lithologic delineation and stratigraphic correlation when used in combination with the others. The Gamma-Gamma Density is used primarily for delineation of coal seams, while the Natural Gamma provides a useful method of determining the clay content of the Coal Valley strata. The Motorized Arm Caliper provides an indicator of shear zones, due to the tendancy of the sheared rock to collapse and form what the drillers refer to as a "washout". The final log, the Single Point Resistance, is used primarily for detecting the water level in the borehole, although some work has been done on identification of water bearing zones using this tool.

3.1.5 Geological Mapping

Mapping of the Pit 13 area was comprised of Area Mapping, which entailed the walking of the exposed faces and recording dip and dip direction of the bedding, fault planes and predominant joints. Wooden stakes were placed at major bedding contacts and structural features. These were later surveyed in order to determine their coordinates and elevation.

The mapping was concentrated in three particular locations of the pit due to the limited amount of rock exposures (Figure 3). The first area was near the east end of Pit 13 on Section 79700E from 39740N to 39550N. The second location was on the walls of the test pit from 39400N to 39650N and from 78300E to 78700E. Finally, the western edge of Pit 13 was mapped along Section 77500E from 39600N to 39950N.

3.1.6 Data Limitations

Due to the topographic and structural features of the north wall, it is thought that it is potentially the most unstable slope in the proposed pit. The face contains several adverse geological structures, is geologically complex, and will have the maximum ultimate slope height in the pit. For these reasons, the corehole drill program, field mapping, and joint surveys were concentrated in this area. Three of the four holes were situated there (Figure 3). The need to direct most activity towards the north wall

limited the amount of geological data which could be collected for the other slopes in the proposed pit.

Although the structure of both the west and east ends of the pit appears to be simpler than that of the central portion, geological data is scarce. In order to adequately resolve both the wall geology and the geometry of the coal deposit in the areas, further drilling is required.

3.2 Geology of the Pit 13 Area

Pit 13 is situated on the northern limb of the Lovett River Syncline, just west of the Reco Fault Extension. The mean orientation of the bedding planes is 135°/15°S (Strike/Dip).

In the proposed pit area, and Mynheer A zone in general, the dominant geologic structure is a slightly undulating anticlinal structure. The Upper Mynheer coal has been squeezed into the crest of this fold, forming a three dimensional pod. Moving down strike in the Pit 13 area, the coal transforms from a shallow lying, elongated wedge to a high, narrow triangular structure and back to an elongated wedge.

The present geological interpretation of the Pit 13 area indicated that jointing patterns and lithologies are similar to those encountered in adjacent mining areas.

3.2.1 Geology of the South Wall

The lithology of the south wall consists of interbedded sandstones, siltstones, and mudstones. Exact stratigraphic correlations from geophysical logging techniques are difficult to determine since the wall is comprised of massive sandstones. Since continuous marker beds such as the Lower Mynheer and Bourne seams are present, it can be inferred that the stratigraphic sequence has not been interrupted laterally by faulting or folding. Bedding planes in the south wall tend to dip gently into the wall at approximately 5 to 20 degrees, although immediately above the limb of the Upper Mynheer coal pod, dips increase to 45 degrees. Near the crest of the coal pod, bedding is considerably disturbed. Vertically dipping strata and overturning are common in this region, with random minor thrust faulting (Figure 8).

3.2.2 Geology of the North Wall

Although the lithologic units are very much similar to the south wall, the geology of the north wall is structurally more complex. In most areas, a cross section through the north wall can be categorized on the basis of stucture into three units. Not all units are present throughout the entire wall as the upper units have been eroded in some areas.

The lowermost unit rises approximately 46 m (150 ft) above pit bottom, and is present along the entire length of

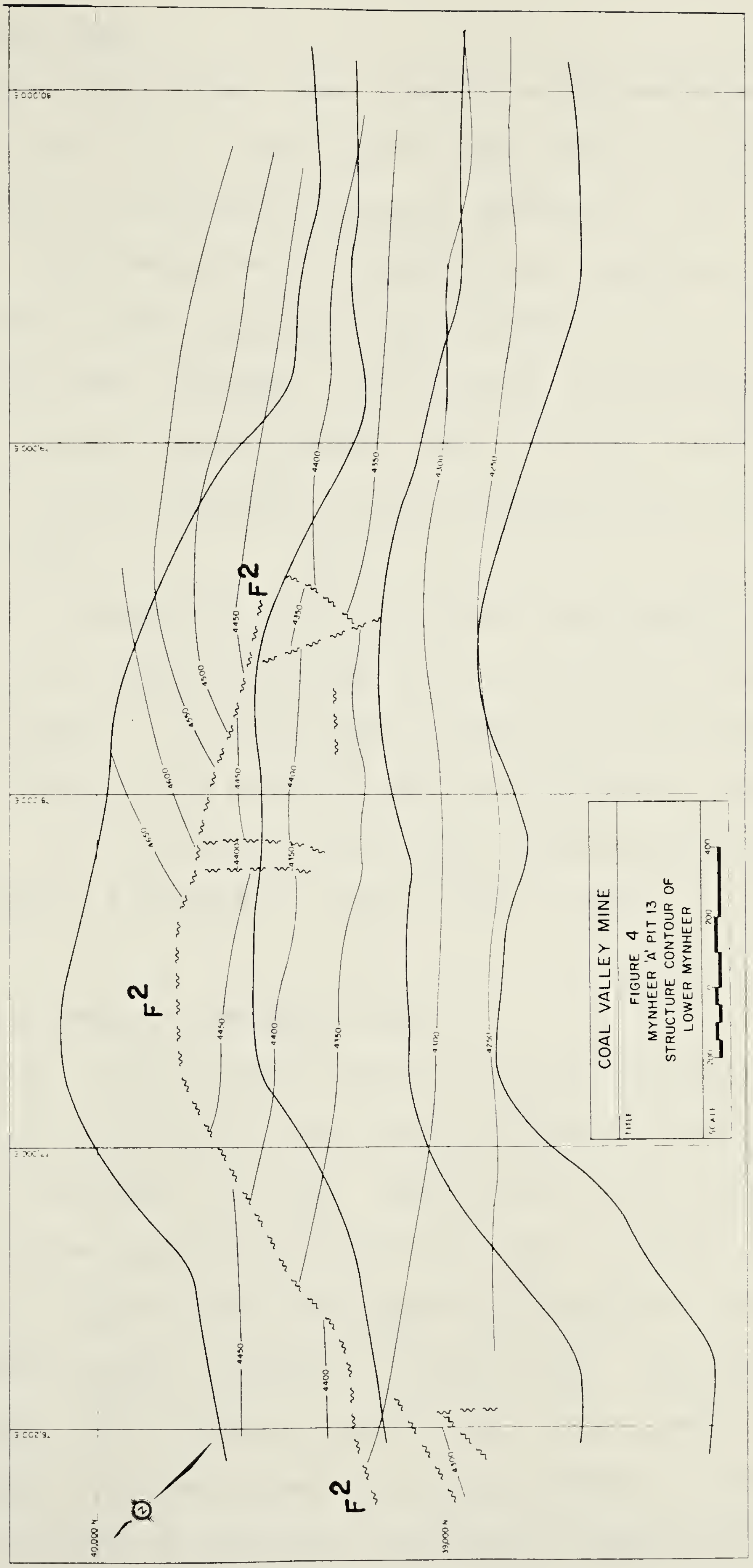
the wall. It consists of relatively uniform strata dipping into the proposed pit at 12 to 18 degrees. The top of this unit is bounded by a low angle (<10°) thrust fault, above which lies a 30 m (100 ft) thick unit which has undergone varying degrees of deformation. Bedding dips of these strata range from horizontal to 10 degrees into the pit. Correlation of the beds is very difficult in this unit since many of the beds have been displaced by minor faults. Immediately above these relatively flat lying strata lies the uppermost unit. Mapping indicates the strata are severely folded and faulted and have undergone intense weathering. This unit is only found east of Section 78200E and above elevation 4730 (Figure 3).

3.2.3 Coal Stratigraphy

In the Coal Valley Mine there are four major coal seams, the Mynheer, Silkstone, Arbour, and Val D'Or. The Mynheer has been divided into an Upper and Lower seam while the Silkstone is comprised of the Wee and Bourne seams. The seams are separated by interbedded sandstones, siltstones, and mudstones of various thicknesses. Both the Silkstone and Mynheer seams are found in the Pit 13 area but only the Upper Mynheer will be mined in the near future. In undisturbed areas the Upper Mynheer is normally between 3 to 9 meters (10 to 30 ft) thick and comprises high volatile Bituminous C coal, interbedded with some minor thin laminations of mudstones and clay. In the Pit 13 area, it

has been tectonically deformed into a 60 to 75 meter (200 to 250 ft) thick pod. The northern edge of the pod is truncated by a steeply dipping reverse fault. Evidence of this fault is obscure in some areas, especially in the eastern section of the pit.

Below the Upper Mynheer lies a 3 to 6 meter (10 to 20 ft) thick series of interbedded coals, carbonaceous mudstones, and clays. This sequence is known as the Lower Mynheer and is very useful as a marker for geological correlation because of its lateral persistence and characteristic Natural Gamma and Focussed Gamma-Gamma Density properties. The Lower Mynheer has not undergone the same thickening process as the Upper Mynheer, but it has been faulted in some areas. The faulting seems to have no discernible influence upon the top of the Upper Mynheer coal pod, but has displaced the bottom of the pod and the Lower Mynheer by as much as 30 m (100 ft). The Lower Mynheer is also affected by the steeply dipping reverse fault which determines the northern edge of the Upper Mynheer coal pod. This fault does not disrupt the Lower Mynheer east of Section 78900E. An approximate outline of the pit boundaries and a structure contour map of the Lower Mynheer are illustrated in Figure 4.


COAL VALLEY MINE
TITLE
FIGURE 4
MYNHEER 'A' PIT 13
STRUCTURE CONTOUR OF
LOWER MYNHEER
SCALE
F2

3.2.4 Marker Beds

The most persistent and readily identifiable marker beds in the Pit 13 area are the coal seams. Of these, the Lower Mynheer is the most prominent because of its lateral continuity and characteristic geophysical signature.

Located in the south wall approximately 75 m (250 ft) above the Lower Mynheer, is the Lower Silkstone or Bourne seam. It is also a useful marker bed but is of limited value for correlation purposes since the seam is not present in the north wall.

A 1 to 3 meter (3 to 10 ft) thick conglomerate found in the north wall may also be useful for correlation purposes. It dips gently to the east at about 12°, outcropping at Section 77700E in the west and Section 78700E in the east. The unit is not easily identified by geophysical methods, but is usually recorded in the Drillers' logs.

3.2.5 Joint Sets of the North Wall

A joint survey was carried out in the uppermost unit of the north wall of Pit 13 near Section 78400E (Figure 3). A lack of exposures in the lower units and difficulty of access in other sectors limited the joint survey to this particular region. Detailed mapping procedures, such as the Line Method which permits statistical analysis and corrections for bias, were not used owing to the considerable time requirements of such methods. Instead, a random Area Mapping technique was used by mapping accessible

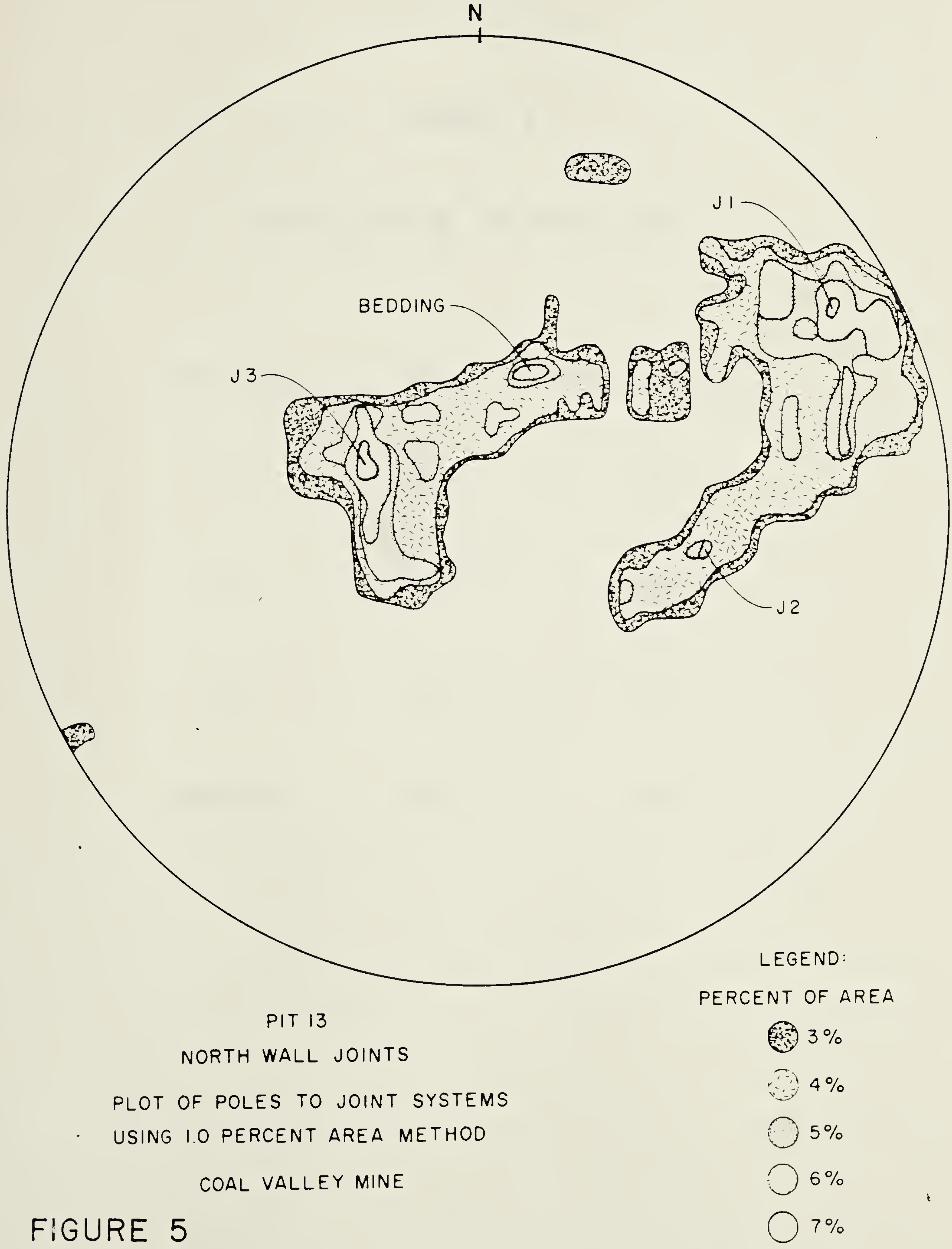
areas with a Clar Compass. This type of mapping is susceptible to sampling bias, which may result from joints which strike almost parallel to face being observed less frequently than those perpendicular to the face. This was hopefully minimized by using a visual selection process in an effort to take a representative sample of the jointing system. Directional bias was also reduced by mapping two mutually perpendicular faces.

A stereographic projection of the poles to the joint planes was compiled from 160 dip and dip direction values. The jointing data were subsequently contoured on Luscar Ltd.'s Hewlett Packard 3000 Computer system using the One Percent Area Method to determine the predominant jointing systems. The computer printout of the contour plot is shown in Figure 5, and indicates 3 major joint sets. Their mean orientations are listed in Table 2.

Of the three major joint sets, J-1 appears to be the most significant with respect to slope stability. Although the spacing (0.5 to 1.0 m) is slightly greater than the other two joint sets, they also appear to be more continuous. Joint planes in the J-1 jointing system exhibiting lengths of 3.0 m (10 ft) are common. The mean orientation of the J-1 system is adverse to pit wall stability, forming a possible weakness plane along the back of a potential failure block.

Calcite infilling was observed on many of the joints in all three of the joint sets, but was generally discontinuous

EQUAL AREA LOWER HEMISPHERE STEREOGRAPHIC PROJECTION



PIT 13

NORTH WALL JOINTS

PLOT OF POLES TO JOINT SYSTEMS
USING 1.0 PERCENT AREA METHOD

COAL VALLEY MINE

FIGURE 5

TABLE 2

JOINT SETS OF THE NORTH WALL

Joint Set	Dip	Dip Direction
J-1	77°	241°
J-2	43°	288°
J-3	23°	101°
Bedding	28°	198°

----

and is unlikely to have a significant affect on stability of the pit walls. Owing to a lack of accessible exposures, no information is available on joint sets of the south wall.

3.2.6 Faulting in the Pit 13 Area

There are two major faults in the Pit 13 region. The first is a laterally persistent, northeast dipping thrust fault which truncates the top of the Upper Mynheer coal pod (F1 on Figure 8). The fault daylights east of Section 78500E, but re-appears in the adjacent Pit 14 area. Near Section 77400E, exposed portions of the coal pod exhibit an overturning of the bedding towards the southwest immediately below the fault. This overturning indicates that the direction of movement of the overlying beds was up-dip and towards the southwest. Such a displacement is unusual for the Mynheer A region of the mine (Figure 2) as movement along other low angle thrust faults in the area is normally towards the northeast. From the direction and amount of movement, it is deduced that the overlying beds are stratigraphically lower than the coal pod. The displacement along the fault must be in the range of several hundred meters because there is no correlation between the over-riding beds and those located in the south wall.

Associated with the low angle fault is a carbonaceous gouge varying from 0 to 30 cm (0 to 12 in) in thickness. The gouge is generally a dark grey to dirty black bentonitic material composed predominantly fine grained, friable coal

intermixed with sandy clays derived from degraded mudstones and sandstones. Cohesion of the material is low and is therefore seldom preserved in core samples due to its changing thickness and variable composition. The variable thickness and composition of the gouge also makes it difficult to recognize in geophysical logs. Examination of the material is thereby limited to relatively few exposures in the old mine workings.

The second major fault in the Pit 13 area is a northwest striking, steeply dipping reverse fault (F^2 on Figures 4, 7 and 8). It delineates the northern edge of the Upper Mynheer and is truncated by the overlying thrust fault. West of Section 78500E, the fault displaces the Lower Mynheer usually in the order of 15 to 30 meters (50 to 100 ft). East of this section, the Lower Mynheer is no longer affected by the fault. The eastern extent of the fault is not known, since earlier mining activities have obscured the pod outline by excavating the coal and by waste dumping.

In addition to the two major faults, there is also a series of northeast striking faults which penetrate the Lower Mynheer and lower portion of the Upper Mynheer coal pod but dissipate within the coal. There is no evidence of these faults along the top of the pod, thus making their exact location and orientation difficult to determine. The geometry of this faulting, shown in Figure 4, was interpolated from the structure contour map of the Lower Mynheer.

3.2.7 Effects of Weathering

The strata in the Pit 13 mining zone are very susceptible to weathering processes. Exposure to the elements causes visible degradation of the sandstones, siltstones, and mudstones, especially in rocks with higher carbonate or bentonite contents. Over a period of just a few months, the breakdown of the sandstone into a cohesionless sand mass has been observed in submerged core samples. More significantly from a geotechnical standpoint, is the effect of weathering upon the bentonitic mudstones, as water tends to reduce the mudstones to soft clays. The colour of the clays will lighten in accordance with the bentonite content of the original mudstone. Evidence of this weathering process has been observed both in the pit walls and in core samples. Mudstone outcrops in the old mine workings have degraded to a depth of about 45 cm (18 inches), grading with distance into the wall from a soft clay to a fractured mudstone to a cohesive mudstone. Over the last 3 years, recent exposures caused by erosion or gullying during spring runoffs have weathered to a depth of approximately 10 cm (4 in), while the original structure of the mudstone is still visible in the clay. Angular fragments and planar jointing are still present in the material which can, however, be easily molded and formed.

Inspection of old core samples, stored outdoors for several years has revealed similar effects. A 1 to 2 cm (1/2 to 3/4 in) ring of clay is present around the perimeter of

the core, while the central portion of the core is composed of a relatively cohesive mudstone.

3.3 Pit 13 Structural Sectors

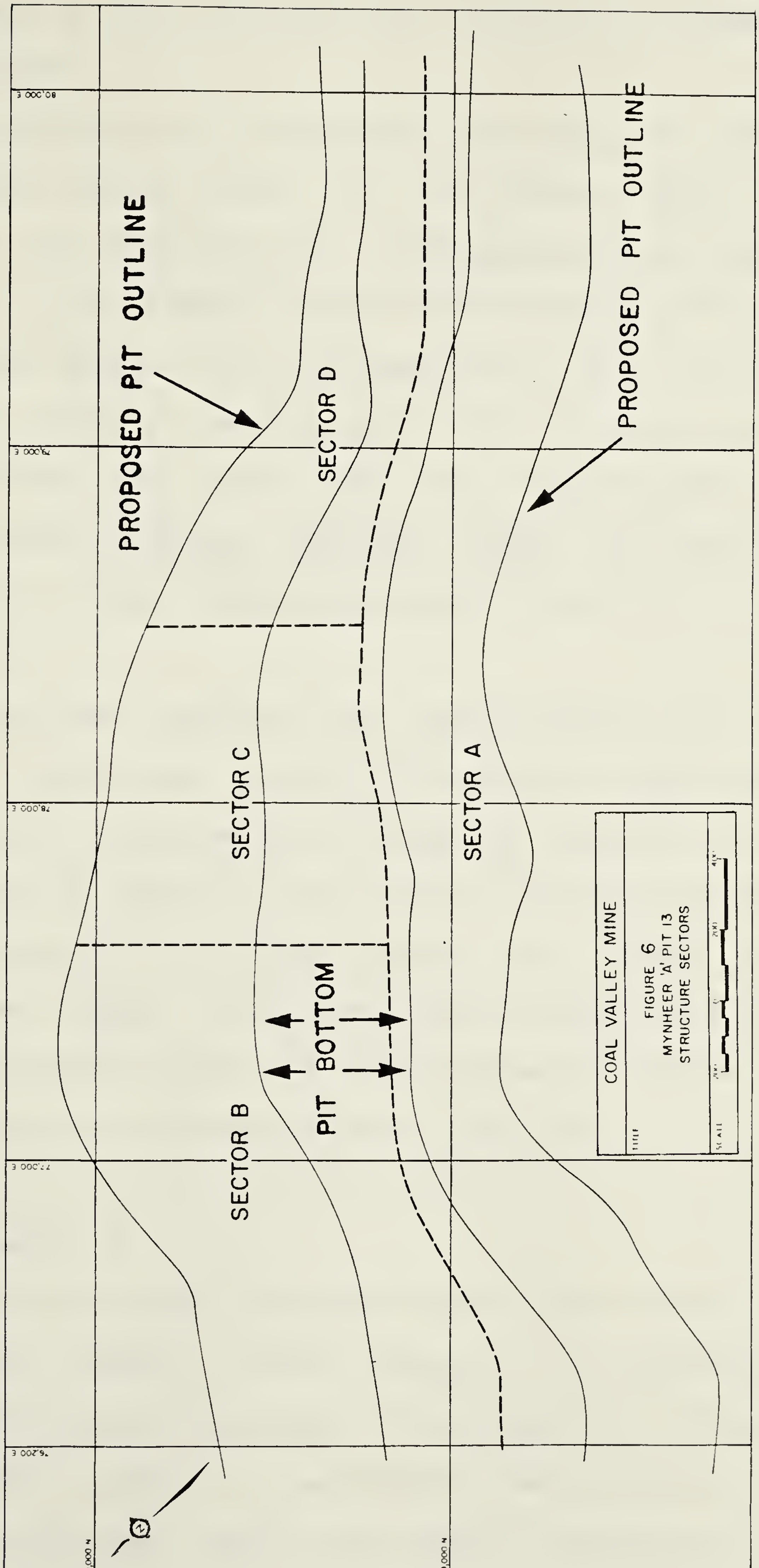
For design purposes Pit 13 has been divided into four geologically distinct sectors primarily on the basis of differences in structure. The division into sectors along the north wall was also founded on the number of the structurally distinct units as described in Section 3.2.2. As a result of differential erosion, not all of these structural units are present in each of the sectors along the north wall. A plan view of the pit area and the individual sectors is shown in Figure 6.

3.3.1 Sector A

Sector A covers the entire south wall of the pit from 76200E to 80000E, a distance of 1160 m (3800 ft)(Figure 6). The geologic structure of Sector A was described previously in Section 3.2.1.

3.3.2 Sector B

Sector B is situated in the northwest corner of Pit 13, covering the area between sections 76200E and 77600E (Figure 6). Slope heights in the proposed pit wall in this sector range from 90 to 107 meters (300 to 350 ft). The eastern boundary is an arbitrary one based on a gradual increase in


PROPOSED PIT OUTLINE
PROPOSED PIT OUTLINE
SECTOR D
SECTOR C
SECTOR A
SECTOR B
PIT BOTTOM
COAL VALLEY MINE
FIGURE 6
MYNHEER 'A' PIT 13
STRUCTURE SECTORS
80,000 E
79,000 E
78,000 E
77,000 E
40,000 N
39,000 N

thickness of the coal pod and structural changes in the overburden.

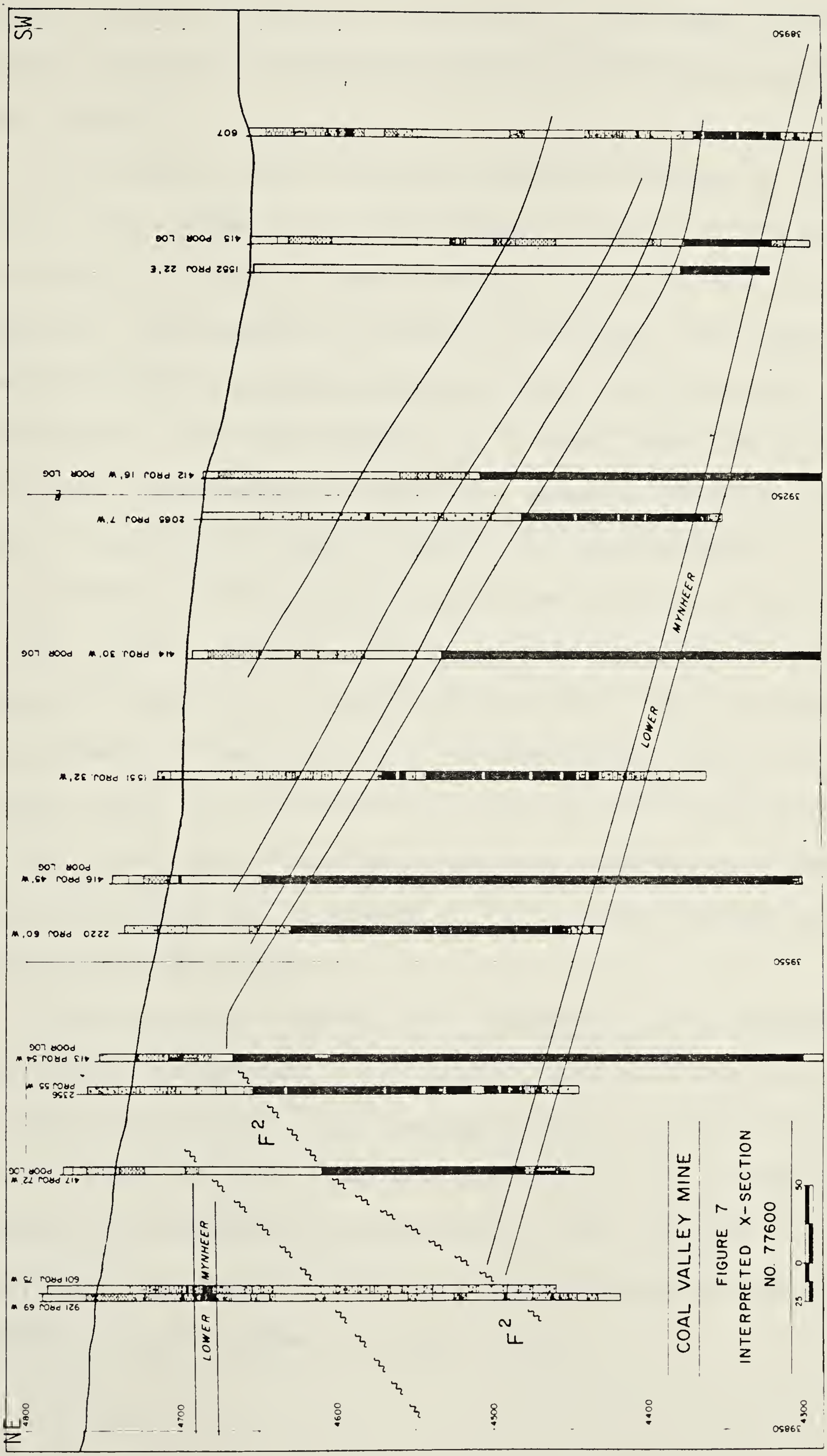
From the very limited data available, it appears that only the strata below the low angle thrust fault are present. For the most part, bedding dips at an angle of 12° to 16° into the pit. Local stratigraphic units, including the Lower Mynheer, are displaced about 15 m (50 ft) by the steeply dipping reverse fault which truncates the northern edge of the coal pod. The fault displacement increases considerably towards section 77400E to a maximum of 60 m (200 ft). A cross section through this sector is provided in Figure 7.

The Lower Mynheer and lower portion of the Upper Mynheer coal pod are also disrupted by a series of faults striking at approximately 45 degrees azimuth. Evidence of these faults appears at the western edge of the sector.

In Sector B the Upper Mynheer coal forms a slightly thickened wedge, with a maximum thickness of 60 m (200 ft) at the northern edge. The wedge gradually pinches out to the south, over a distance of 245 m (800 ft).

3.3.3 Sector C

Sector C constitutes the central portion of the north wall from 77600E to 78500E (Figure 6). The eastern boundary, similar to that of the west, is an arbitrary choice based on a gradual change in the shape of the coal pod. This sector contains the most complex geological structures of the pit.



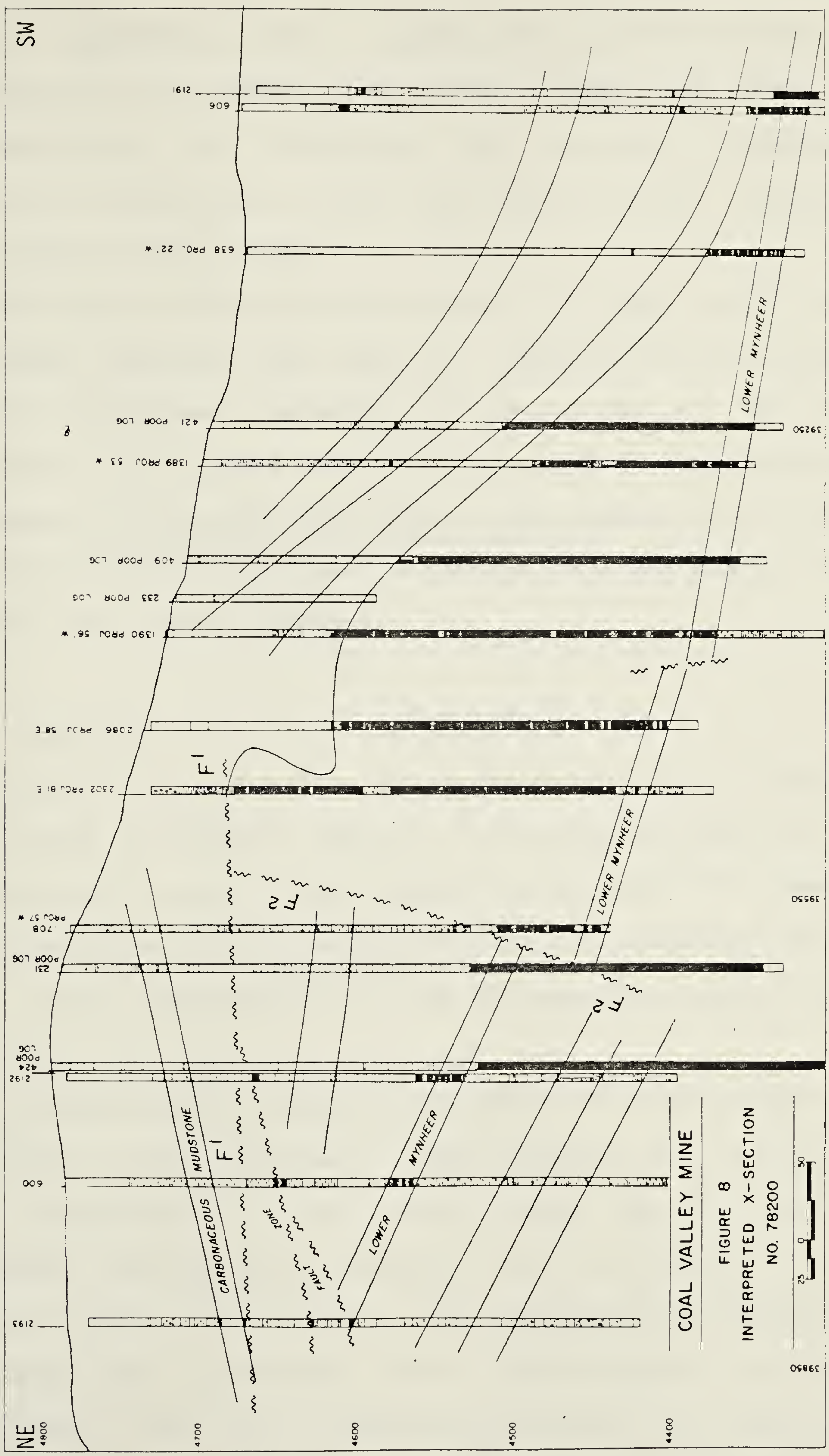
COAL VALLEY MINE

FIGURE 7
INTERPRETED X-SECTION
NO. 77600

There is severe folding and faulting in the upper portion of the wall as well as frequent jointing and fracturing in the lower strata.

All three of the structural units discussed in Section 3.2.2. are present in this sector (Figure 8). The beds in the lowest unit dip at approximately 18° into the pit and comprise interbedded siltstones, mudstones, and sandstones. The sandstones are generally calcareous and contain coaly inclusions. The Lower Mynheer is located near the bottom of this unit. Displacement along the steeply dipping reverse fault is similar to that in Sector B, approximately 15 m (50 ft). Borehole information is more plentiful here than in any of the other sectors, thus permitting a fairly accurate determination of the location of the fault and the amount of displacement. The fault is truncated by a gently dipping reverse fault (F^1 on Figure 8), which also truncates the top of the coal pod. This fault has been removed by erosion in Sectors B and D, but evidence of it is found further east in adjacent mining areas.

The second unit above the reverse fault consist of intermixed sandstones, siltstones, and mudstones which dip at approximately 10° into the north wall. The sandstones are either severely fractured and weathered tabular deposits or randomly jointed massive sandstones. Also included in this sequence, is an 2.5 m (8 ft) thick conglomerate containing rounded to sub-rounded siliceous clasts.


COAL VALLEY MINE
FIGURE 8
INTERPRETED X-SECTION
NO. 78200
NE
SW
4800
4700
4600
4500
4400
CARBONACEOUS MUDSTONE
LOWER MYNHEER
LOWER MYNHEER
LOWER MYNHEER
FAULT ZONE
F1
F1
F2
F2
2193
600
2192
424 POOR LOG
231 POOR LOG
708 PROJ 57 W
2302 PROJ 81 E
2086 PROJ 58 E
1390 PROJ 56' W
233 POOR LOG
409 POOR LOG
1389 PROJ 53 W
421 POOR LOG
638 PROJ 22' W
606
2191
39850
39550
39250

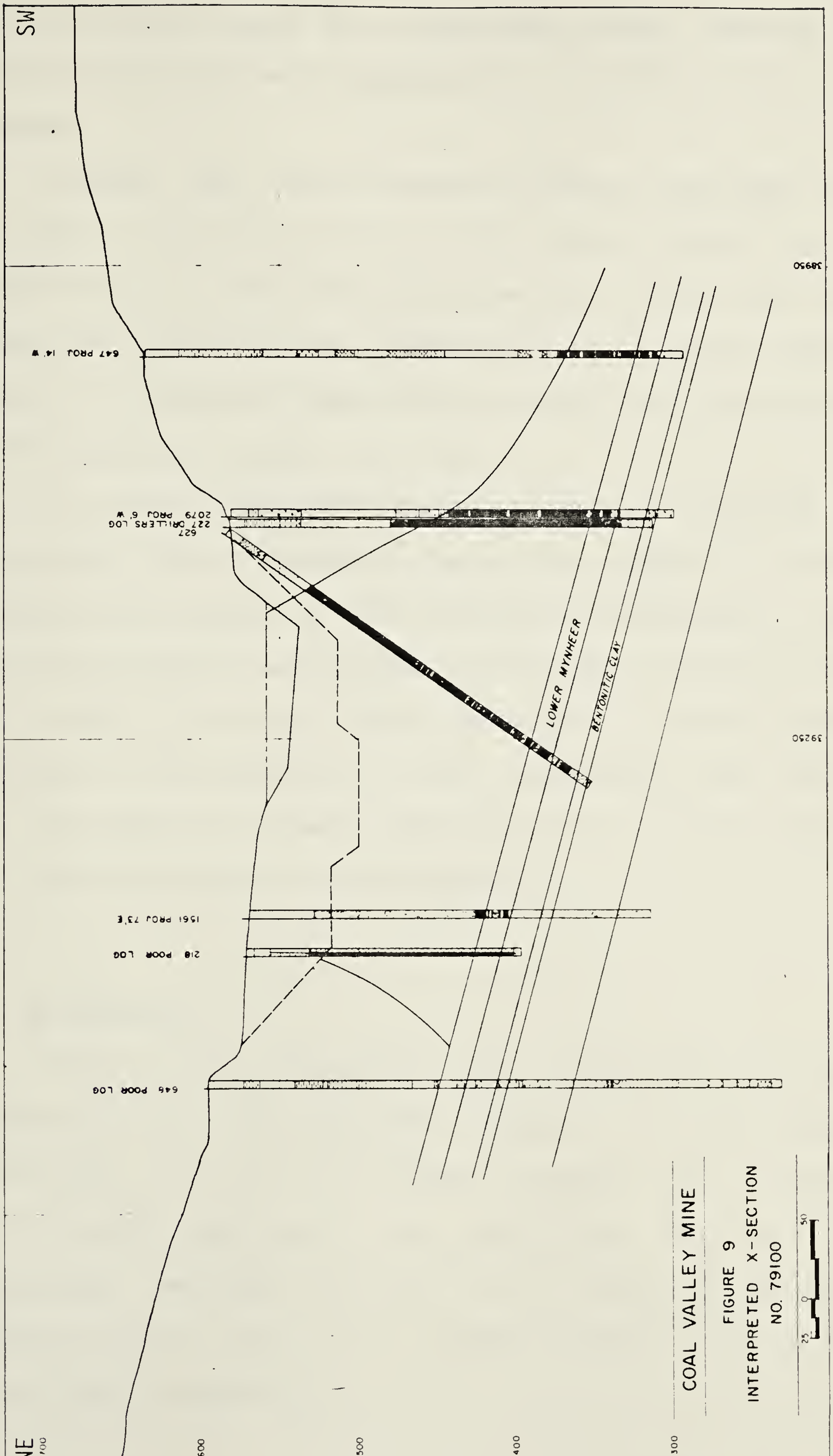
The uppermost unit, located above elevation 4730, is geologically very complex. The strata, comprised primarily of sandstones and siltstones, are extremely weathered, intensely fractured by joints and faults, and frequently overturned or drag folded.

Relative to the other two sectors in the north wall, the Upper Mynheer coal pod in Sector C has a greatly increased thickness, reaching a maximum of 90 m (300 ft). The flanks of the pod steepen to a maximum of 70 degrees and 60 degrees on the north and south sides respectively, while the overall width of the pod decreases to a minimum of 107 m (350 ft) near Section 78500E.

3.3.4 Sector D

Sector D is located in the northeast corner of the pit, from 78500E to 80000E (Figure 6). The maximum height of the proposed pit wall in this region is 75 m (250 ft). General characteristics of this sector include an elongated coal pod with little deformation of the surrounding strata (Figure 9).

The geological structure of Sector D is the simplest of any sector in the north wall. There appears to be little, if any, displacement of the Lower Mynheer due to either the northeast trending fault system or the northwest striking reverse fault. The strata are predominantly composed of mudstones and siltstones with interlayered calcareous sandstones. Only the lowermost structural unit remains in



COAL VALLEY MINE

FIGURE 9
INTERPRETED X-SECTION
NO. 79100

Sector D as the upper units have been eroded. Bedding planes tend to dip relatively consistantly into the pit at 11 to 13 degrees.

Towards the eastern edge of the pit the Lower Mynheer outcrops, revealing a 0.3 m (1 ft) thick clean coal seam underlain by a bentonitic mudstone and a dirty coal seam. A recent pit bottom survey indicates the old mine operations simply followed the Lower Mynheer down dip, and removed the overlying Upper Mynheer coal pod.

In Sector D the Upper Mynheer forms an elongated wedge. The extent and thickness of the northern edge is difficult to determine because of the old mine workings but it appears that the original pod reached a thickness of approximately 45 m (150 ft) and was about 150 m (500 ft) wide. Because of the water which collected in the abandoned mine workings, drilling has not been carried out in this sector to delineate the remaining coal deposit.

3.4 Groundwater

Single open standpipes were installed in each of coreholes 2192, 2193 and 2194 (Figure 3). The standpipes consisted of 3.8 cm (1.5 inches) diameter (O.D.) PVC tubing with glue-on couplings. The perforated sections of the standpipe consisted of a 3 m (10 ft) length of standard PVC tubing in which 0.25 cm (0.1 inches) wide by 5 cm (2 inches) long slots had been cut.

Installation of the standpipes began by placing an end cap on on a 3 m (10 ft) length of standard tubing. The slotted section was connected to the top of the capped length and successive lengths of tubing were added to the screening until it reached the desired depth (Table 3). The bottom, capped piece of tubing provides a sump to collect sediments and minimize plugging of the perforated section. During assembly, the piezometer is held by the couplers with a metal slip. As each length is added to the standpipe, the slip is removed and the tubing is lowered into the hole. Upon completion of the standpipe, washed pea gravel was placed in the hole around the circumference of the tubing. The piezometers were designed for measurement of the local groundwater level and were not sealed at any particular intervals with packers, bentonite, etc.

Immediately after installation, the water level in each of the piezometers was measured with a direct sensing electric probe. However, subsequent monitoring of the three standpipes has been very irregular. Data from these piezometers and from holes drilled in the adjacent Pit 14 area suggest that the groundwater table elevation is seasonably variable and ranges from 18 m to 30 m (60 to 100 ft) below grade.

A hydrogeological study was completed in the eastern end of Pit 14 in May 1979. The relevance of this data to the Pit 13 area is uncertain, however, a visual examination of the region would indicate that a number of the conclusions

----

TABLE 3

STANDPIPE PIEZOMETER INSTALLATIONS

Corehole Number	Depth of Screened Interval m	ft	Lithology of Screened Interval
2192	61-64	200-210	Aphanitic Mudstone
2193	30-33	100-110	Silty Mudstone
2194	87-90	285-295	Silty Mudstone

----

for the study will prove valid for Pit 13 as well:

1. the direction of the local groundwater flow is southwest from the northwest striking ridge.
2. the permeability of the rock discontinuities is greater than that of the intact rock.
3. groundwater flow is highly dependent upon the geologic structure of the rock mass, especially attitude and spacing of joint and bedding planes.

Hydrologic characteristics of Pit 13, such as rock permeabilities, are not known.

4. Laboratory Rock Testing Program

Samples for the Pit 13 testing program consisted of 80 core samples taken from four geotechnical coreholes. Approximately 20 grab samples were also taken from outcroppings near the old mine workings.

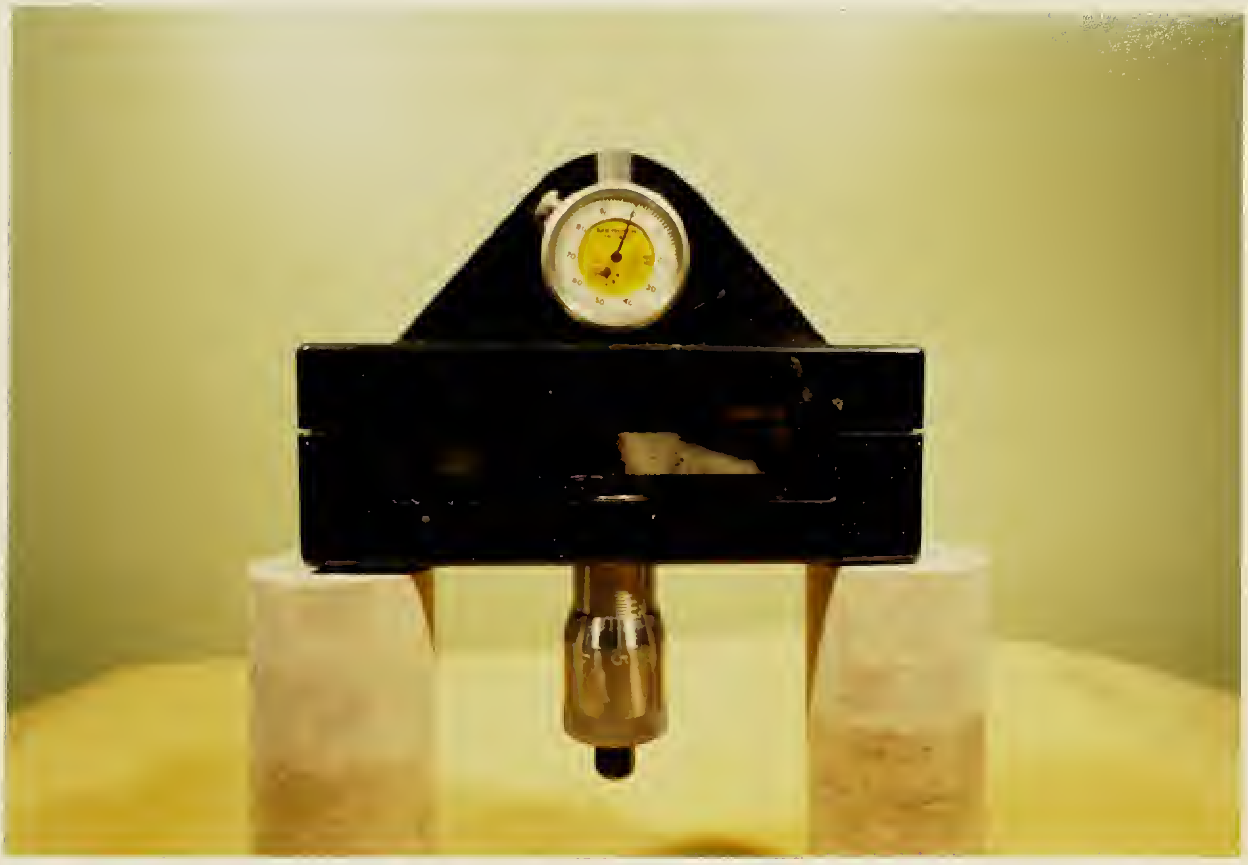
The testing program comprised 38 moisture content determinations, 2 24-hour water absorption tests, 22 direct shear tests, 3 Atterburg Limit tests, 9 density determinations, 23 Brazilian Disc tests, 17 uniaxial compression strength tests (solid steel platens), 11 uniaxial compression strength tests (brush platens), 3 static modulus of deformation tests, 45 NCB Cone Indenter tests, and 1 triaxial compression test (at 5 confining pressures). The laboratory rock testing program was divided into two independent studies. The first study was primarily concerned with measuring or estimating the intact strength properties of Pit 13 strata. To this end, a series of Brazilian disc, uniaxial compression, and NCB Cone Indenter Tests were carried out on the sandstones, siltstones, and mudstones of the Pit 13 area. The Brazilian disc and uniaxial compression tests were performed in accordance with guidelines described in Supplement 3-1 of CANMET'S Pit Slope Manual (1977). A description of the NCB Cone Indenter and method of use are given in this Section. A summary of the test results is provided in Appendix B.

The Pit 13 strength testing program, with the exception of the NCB Cone Indenter and brush platens was typical of

most slope design test programs. The Cone Indenter was originally developed by the National Coal Board (NCB) of Britain at the Mining Research and Development Establishment (MRDE Report No. 19, 1971). The device is presently manufactured by Howard's Engineering (Derby) Co., Derby, England.

The Cone Indenter is composed of a flat metal spring solidly attached at both ends in a portal steel frame (Photo 4). Overall dimensions of the device is approximately 18 cm by 20 cm (7 by 8 in). A carbide steel point is fitted into a hollow stemmed micrometer in order to measure penetration. Deflection of the spring is measured by a dial gauge attached directly to the frame (MRDE Handbook No. 5, 1977). A rock chip not larger than 12 mm by 12 mm by 6 mm (0.5 by 0.5 by 0.25 in) is placed between the steel spring and the carbide point and the micrometer is zeroed. A predetermined force (proportional to the deflection of the spring) is applied by rotating the micrometer, and the resulting penetration of the point into the sample is measured. Corrections are made for deflection of the spring and a final penetration measurement is obtained. An indenter index number is derived by dividing the deflection of the spring at the applied force by the penetration of the carbide tip into the sample. This value, called the Cone Indenter number, is then multiplied by a correction factor to obtain the uniaxial compressive strength of the rock. The relationship developed by the National Coal Board is given

PHOTO 4



NATIONAL COAL BOARD CONE INDENTER

by:

$$\sigma_c = 24.8 \text{ CI}$$

where σ_c = uniaxial compressive strength, CI = the Cone Indenter number.

The second exception to an otherwise typical slope design strength testing program was the brush platens. The platens were originally developed by E.T. Brown and L.P. Gonano (1974) to permit testing of samples with length/diameter ratios less than 2:1. They are designed to minimize the frictional force between the material being tested and platens, thereby reducing the constraint experienced by the sample at its ends. The platens are constructed of a matrix of steel pins which are long and, therefore, flexible enough to allow expansion of the rock sample, but short enough to maintain pin stability. The brush platens manufactured for testing Coal Valley rock consisted of 0.3 cm by 0.3 cm by 5.1 cm (1/8 by 1/8 by 2 in) steel keystock held in a circular clamp (Photo 5).

The testing conducted by Brown and Gonano to evaluate their platens was performed on specimens of relatively strong, Wombeyan marble of varying lengths. Comparative tests were also carried out using solid steel platens. It was found that the increase in strength with decreasing length to diameter ratios associated with solid platens was negligible with brush platens.

The second study was concerned with measurement of the direct shear strength of the weaker strata of Pit 13, such

PHOTO 5

BRUSH PLATENS

as the coals, clays and bentonitic mudstones. For the most part, the determination of the shear strength of lithological contacts was the primary aim of the tests (e.g. coal/mudstone contact), which were conducted in a Leonard Farnell 10 cm by 10 cm (4 by 4 in) direct shear box in accordance with procedures outlined in Supplement 3-2 of CANMET'S Pit Slope Manual. In order to minimize sample disturbance, each sample was tested under increasing incremental normal loads. A typical sample would be sheared under five normal loads ranging from 75 N to 1500 N (17 to 337 lbs) at a strain rate of 0.013 mm/min (0.0005 in/min).

4.1 Corehandling and Sampling Techniques

In order to examine the core, the 7.6 cm (3 in) inner plastic tubing was opened on the drill site using an electric router and portable generator. The core was inspected for core recovery and for the selection of representative samples for testing. From the four geotechnical holes 89 samples were collected. Each sample was briefly described, measured, and the exact depth from which the sample was taken recorded.

The samples were left in the plastic tubing which was wrapped in plastic bags and inserted in 9 cm (3.5 in) PVC tubes. The ends of the tube were sealed with either plastic sampling bags and fibre tape or paraffin wax. Finally, the samples were transported to the Rock Mechanics Laboratory at

the University of Alberta and stored in a non-operating freezer. The freezer contained 5 cm (2 in) sheets of saturated foam rubber, which were placed over the samples in order to retain the specimen's natural moisture.

The remaining core from Coreholes 2191, 2193, and 2194 was placed in 1.5 m (5 ft) long wooden core boxes and geologically logged and photographed in Luscar's portable core shack at Coal Valley. The lids were then placed on the core boxes and the core was stored on site for future reference. The core from CH2192 was left in the core tubes and sealed in blasthole loading bags with fibreglass tape. These were taken with the selected samples to the University of Alberta and stored in the basement of the Chemical-Mineral Engineering Building.

4.2 Selection of Laboratory Tests

4.2.1 Strength of Intact Rock

There are several types of design tests commonly used to determine intact rock strength parameters for slope analysis purposes. The uniaxial and triaxial compressive strength tests, as well as direct tension testing are examples of design strength tests. Index testing methods used for slope design would include the Schmidt Hammer (dynamic rebound test), Point Load test, 24-hour absorption test, density tests, and water content determinations. The

major limitation of the various testing techniques for slope design purposes, is the problem of estimating the rock mass properties from the intact rock properties. There does not appear to be a simple solution to this problem, however, the intact testing does provide background information so that rock mass parameters can be more accurately estimated using judgement and experience.

The testing methods selected for the Pit 13 intact rock strength testing program included a variety of design and index tests in order to determine several of the intact rock mechanical properties. The static strength properties of the Pit 13 samples was measured using the Brazilian Disc, uniaxial compression, triaxial compression, and NCB Cone Indenter testing, while the affects of stress on the Coal Valley strata was examined by the static modulus of deformation test. Physical properties of the intact rock were examined using density and moisture content determinations as well as the 24-hour absorption test.

The strength properties of the intact Coal Valley strata could have been determined using standard tests, such as the uniaxial compressive test, direct tension, or triaxial compressive test. However, these tests require expensive testing machines and tedious and sometimes difficult sample preparation. For this reason, index tests such as the Point Load test and Brazilian Disc test are often used to indirectly estimate the strength properties of a rock. According to Broch and Franklin (1972), an index

test is a test which is quick, accurate, and inexpensive enough to be used for classification and mapping applications. In order to fulfill these requirements, the index test must be simple and reproducable.

Although the Point Load test is more tolerant of structural irregularities in rock specimens that line load tests such as the Brazilian Disc, experience with many rocks in the Coal Valley area has shown that Point Load index testing has not given accurate and reproducable results. It is believed that this test is not suited to the soft rock encountered in the study area because the failure mechanism in these rocks may differ from that assumed for analysing the test data. Failure of soft rocks in the Point Load test often occurs by crushing of the rock under the conical end points, whereas the assumed failure mechanism involves propagation of a tensile fracture from the centre of the specimen towards the conical end points.

In an attempt to acquire a suitable strength index test for the Coal Valley area, it was decided to evaluate the NCB Cone Indenter. Cone Indenter tests were conducted on mudstone, siltstone, and sandstone core samples taken immediately adjacent to uniaxial compressive specimens in order to correlate the results of the two tests. During this stage of the testing program, however, it was found that a sufficient number of uniaxial compressive specimens could not be obtained for the correlation purposes.

Several attempts to obtain smaller diameter specimens by under-coring the 6.6 cm (2.6 inch) diameter core using both water and air as lubricants were unsuccessful, even when the core was set in plaster. The difficulty in preparing Coal Valley core samples of adequate length to conduct standard uniaxial compression tests with length/diameter ratios of 2:1 to 3:1 led to the construction and trial of brush platens.

4.2.2 Strength of Discontinuities

In order to determine the shear strength of the Pit 13 Strata a series of direct shear tests were conducted on a variety of samples. The shear properties of the softer rocks and clays in the Pit 13 area are very significant to the stability of the pit walls. This is especially true of the north wall where the Lower Mynheer, underlying the coal pod, has an average dip of 12 to 18 degrees into the pit. The bottom portion of the Lower Mynheer is composed of a 0.3 m to 0.6 m (1 to 2 foot) thick, clean coal seam overlain by interbedded bentonitic mudstones, making the sequence a critical factor in the stability of the proposed pit wall. Formation of even a very thin clay layer along the coal-mudstone contact would form a potential failure surface that would affect the stability of the entire wall.

Owing to the significance of the strata shear strength properties, tests were performed both on the mudstone and clay core samples. Further tests were conducted on grab

samples containing either clay-coal, mudstone-coal, or clay-mudstone contacts. Finally, an artificial "sandwich" was constructed of a coal and mudstone sample separated by a 1 cm (0.4 inch) clay infilling, to simulate the possible occurrence of a very thin clay layer along a coal-mudstone contact in the Lower Mynheer.

4.3 Results of the Testing Program

Results of the testing program indicate that the rocks in Pit 13 can be categorized into 6 different types based on their strength properties. For the most part, these categories mirror the five major lighological divisions of coals, clays, mudstones, siltstones, and sandstones. A further division was made between the light grey to brown bentonitic mudstones and the dark grey to green mudstones. The latter group is often chloritic and generally grades to siltstone or sandstone. The strength properties of these darker mudstones are generally higher than those of the bentonitic variety. For this study, the darker mudstones have been classified as silty mudstones, although this may be somewhat of a misnomer, since the name is founded on their strength properties and their mechanical similarities to true siltstones rather than by grain size. On the basis of the strength properties of the available samples, a similar division of the siltstones and sandstones was not observed. Any further sub-division of the rock types was not

attempted due to the limited volume of test data.

The strength properties of the strata sampled in Pit 13 were found to be similar to those obtained in earlier testing of rock samples from adjoining pits. As a result, much of the data obtained from this study may be used for design analysis of future mine development in areas of similar lithologies. An average sample description and detailed record of the test data for each lithologic unit is provided in Appendix B.

4.3.1 Evaluation of the Cone Indenter

On the basis of the limited amount of work carried out on the NCB Cone Indenter during this study, two tentative conclusions were drawn:

1. Results from the Cone Indenter are reproducable; eg. repeated tests on the same specimen generally produced results within 10% of each other.
2. The Cone Indenter results correlated reasonably closely to the actual uniaxial compressive strength results, but did not follow the correlation developed by the National Coal Board.

Figure 10 shows the National Coal Board's relationship and actual test results from compression testing of Coal Valley samples. Only 60% of the data points fit within the limits of one standard deviation about the NCB line.

A linear regression was conducted on the Pit 13 data, resulting in a best fit line given by the expression:

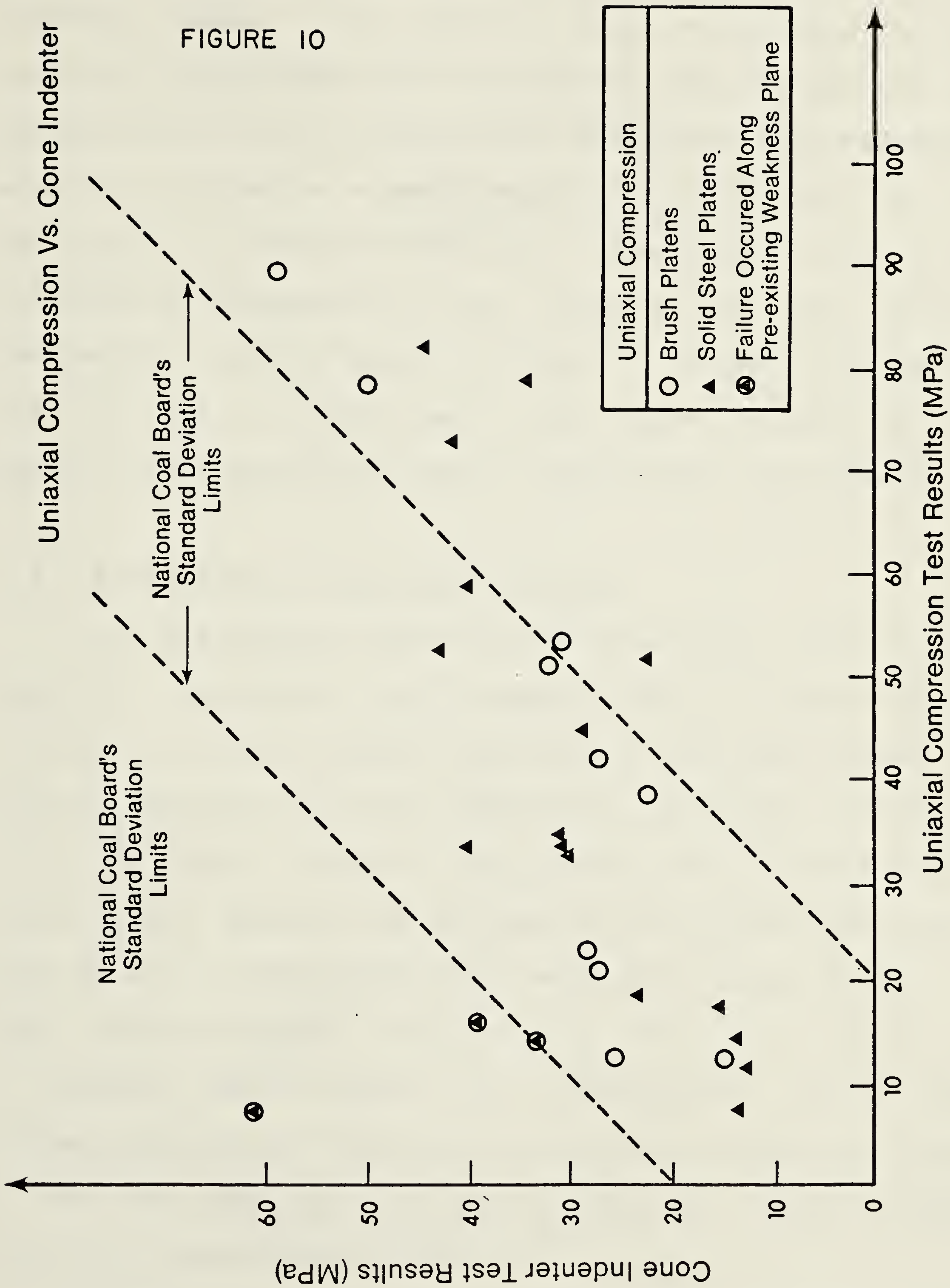


FIGURE 10

Uniaxial Compression Vs. Cone Indenter

$$\sigma_c = 45.3\ CI - 15.9$$

where σ_c = uniaxial compressive strength, CI = the Cone Indenter number. The standard error of estimate for this relation is $\pm$13.3 MPa. The correlation coefficient of the regression is +0.85. It should be noted that this regression equation is based on a small amount of data and is only applicable to strata in the Coal Valley area. A plot of the relationship between the Cone Indenter and the uniaxial compression test is shown in Figure 11. A best fit line for the test data is illustrated in the figure, as well as the general relationship derived by the National Coal Board.

4.3.2 Evaluation of the Brush Platens

In a preliminary evaluation of the brush platens, two separate approaches were attempted. The first approach was to test artificial plaster specimens of varying lengths, but having identical uniaxial compressive strengths. Twenty 5.4 cm (2.126 inches) diameter core samples were drilled from a large block poured from a single mix of plaster and water. Five uniaxial compression tests were carried out on each of four length/diameter ratios; 2:1, 1:1, 0.5:1, 0.25:1. The 2:1 samples were tested with conventional, solid steel platens. Results of these tests are given in Table 4. A plot of the mean compressive strengths for each length/diameter ratio is illustrated in Figure 12.

In order to analyse the testing data, a comparison of means test was conducted using Student's t test (Neville and

CONE INDENTER NUMBER VS. UNIAXIAL COMPRESSIVE STRENGTH FOR COAL VALLEY SAMPLES

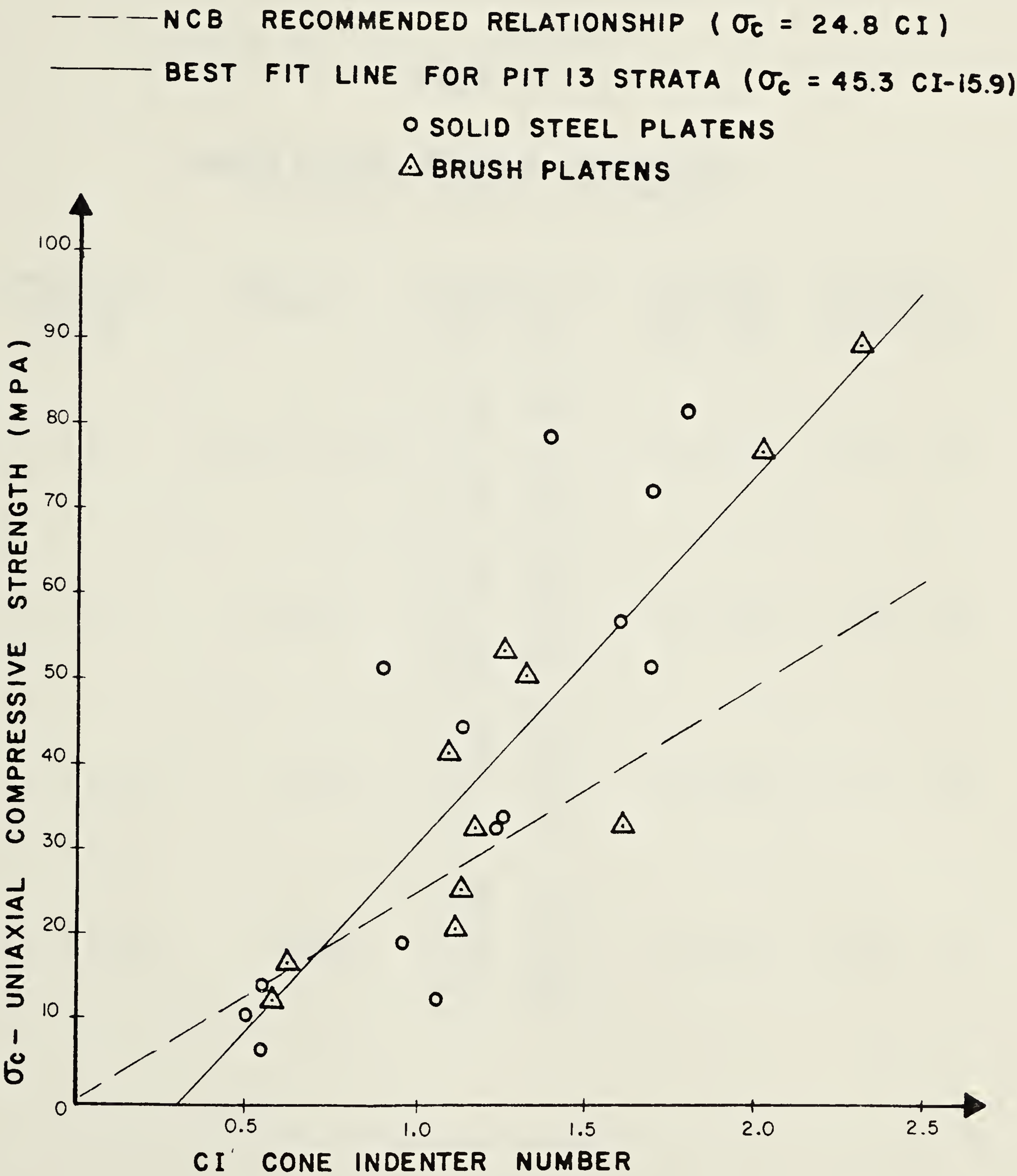


FIGURE 11

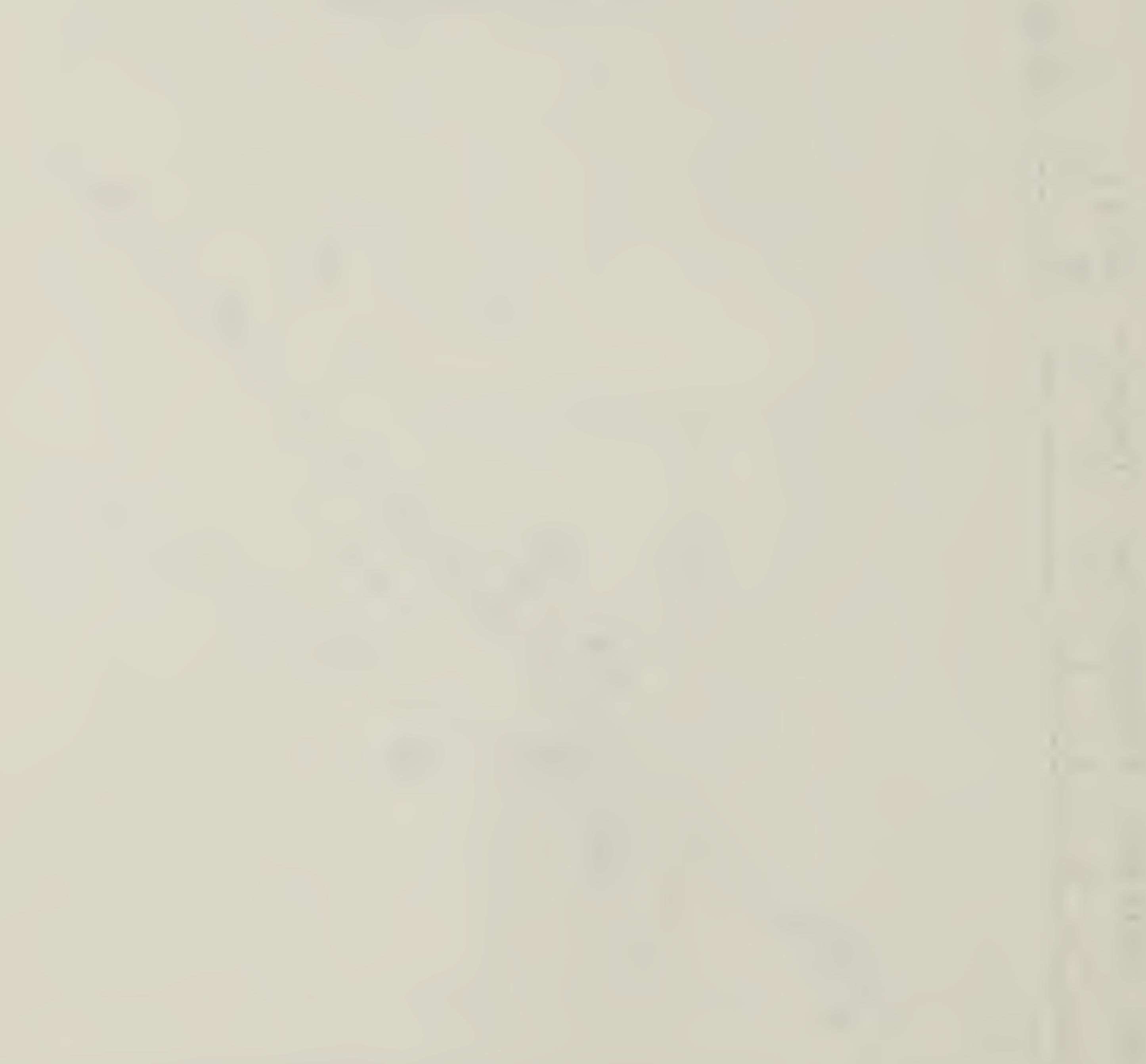


TABLE 4

BRUSH PLATEN UNIAXIAL COMPRESSION TESTING OF PLASTER SPECIMENS

Length to Diameter Ratio	Type of Platens	Compressive Strength MPa	Compressive Strength psi	Average Strength MPa	Average Strength psi	Standard Deviation MPa	Standard Deviation psi
		3.09	448				
		2.60	377				
2.0	solid steel	2.35	341	2.66	386	0.30	43
		2.45	356				
		2.80	406				
		3.16	458				
		2.97	431				
1.0	brush	3.41	495	3.01	436	0.45	65
		2.26	328				
		3.24	470				
		2.83	411				
		2.39	347				
0.5	brush	2.56	372	2.65	384	0.19	28
		2.61	379				
		2.84	412				
		1.89	274				
		2.23	323				
0.25	brush	2.30	333	2.14	311	0.16	23
		2.21	321				
		2.10	304				

UNIAXIAL COMPRESSIVE STRENGTHS
OF
PLASTER SPECIMENS WITH VARYING
LENGTH/ DIAMETER RATIOS

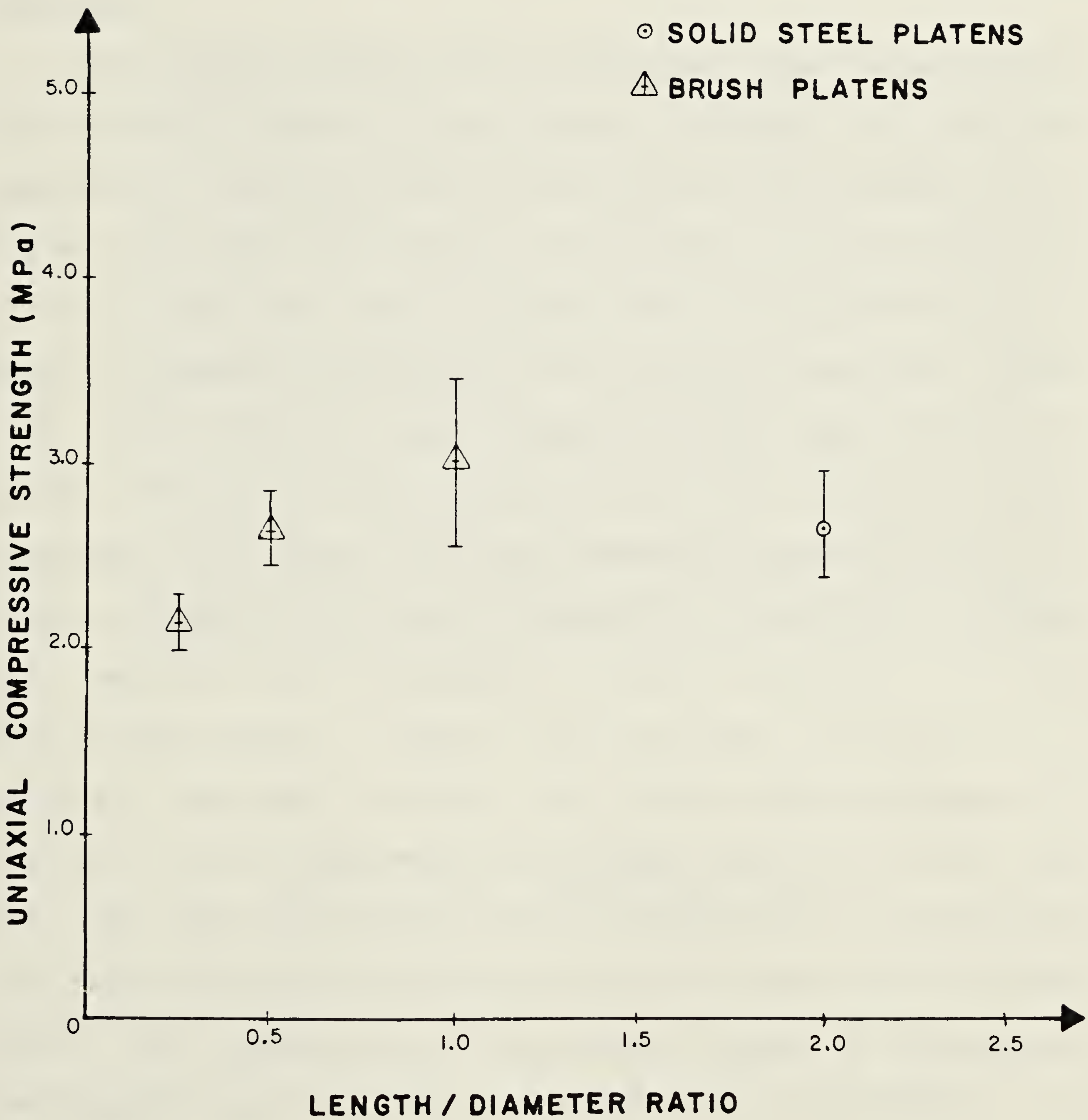


FIGURE 12

Kennedy, 1964) to a 5 percent significance level. Results of the t test indicated no significant difference between the 2:1 and 1:1 ratios as well as between the 2:1 and 0.5:1 ratios. A significant difference was found, however, between the 2:1 and 0.25:1 samples. Further research is necessary in order to produce more conclusive results with plaster specimens.

The second method for assessing the brush platens consisted of testing rock samples adjacent to uniaxial compressive specimens which were tested with standard solid platens and comparing results. The number of tests conducted in this way was very limited due to the difficulty in obtaining samples from core. Examination of specimens tested with brush platens did, however, reveal some interesting points. The angle to the core axis of the failure planes averaged 83 degrees, as the specimens appeared to fail in tension (Photo 6). It was not possible to determine whether the tensile crack propagated from the centre or from the ends of the sample. A typical failure plane inclination in uniaxial specimens tested with solid platens averaged 70° and for triaxial specimens the average angle of failure was 64°. The observed failure plane configuration is consistant with other work done with brush platens (Brown and Gonano, 1974). The formation of end cones, common in compression testing with solid platens, was completely eliminated.

PHOTO 6

BRUSH PLATEN TESTING SPECIMENS

4.3.3 Further Application of the Cone Indenter

The NCB Cone Indenter has potential for a variety of purposes. For example, Stimpson and Ross-Brown (1976) used point load index testing for estimating the cohesive strength of a randomly jointed rock mass. It is suggested that the Cone Indenter could be applied in a similar manner at Coal Valley during the feasibility stage of a geotechnical investigation.

The Cone Indenter has also been used to predict the cuttability of rock by tunnelling machines (McFeat-Smith, 1977). McFeat-Smith suggests that the cutting action of drag-pick tools is predominantly an indentation action and that a relationship exists between the cone indenter hardness and the performance of tunnelling machines employing drag-pick tools.

In addition, Hoek and Brown (1980) have suggested that a simple index test for predicting the uniaxial compressive strength of a rock may be used to estimate triaxial strength envelopes with an empirical strength criterion. The cone indenter index would be particularly useful for this purpose, as accuracy would increase with use. The Cone Indenter could also be used at the exploration stage to correlate and map rock units of similar strengths. The index may also prove valuable in blasting and drilling by providing an estimation of the rock "blastability" and "drillability".

5. Pit 13 Slope Stability Analysis

5.1 Slope Analysis Methods

Two of the most common analysis methods used for slope stability studies are the Stress-Strain Design Method and the Limiting Equilibrium Method. Other design approaches which may be used alone or in conjunction with the Stress-Strain or Limiting Equilibrium Methods, include the Engineering Rock Classification, Experience, Physical Modeling, and Inverse Methods (Stimpson, 1979).

Perhaps the most popular Stress-Strain Design Method used for slope stability purposes is the Finite Element Model. It is generally more versatile than other methods such as the Dynamic Relaxation and Face Element Approach. The major limitation of the Stress-Strain Design Methods, however, is that they are not applicable to large displacement problems. Owing to the magnitude of displacements typically associated with Coal Valley slope movements, it was thought that this type of design method would not be appropriate for the Pit 13 study.

5.1.1 Limit Equilibrium Analysis Methods

The analysis method chosen for this study was the Limiting Equilibrium Model. There are several Limit Equilibrium models which can be used for slope stability analysis including the Friction Circle, Method of Slices,

Generalised and Simplified Janbu, Spencer, and Morgenstern-Price (Chowdhury, 1978). Each of these methods has particular features which may or may not be appropriate for any given stability study.

The Friction Circle method is only suitable for homogeneous deposits. However, where some inaccuracies can be tolerated, it may be applied to non-homogeneous materials. Since it is one of the simplest methods it is often used for slopes in which failures are not critical. Probable situations in which the Friction Circle method would be applied includes; strip mine hangingwalls which are composed of tills and clays, or spoil piles consisting of soils or badly broken rock. The Friction Circle method can also be used for pit walls in broken or badly weathered rock which acts in a soil-like manner, as well as for embankments in homogeneous soils.

The Method of Slices is generally applied to non-homogeneous soils only if a circular failure surface is expected. The inter-slice forces are ignored, thereby reducing the number of calculations necessary to derive a solution. Errors often arise if the failure surface has a steep negative slope near the toe. As a result, the method of slices is generally used for long slopes in stratified deposits.

Where slopes are likely to have high pore water pressures, the Janbu Method may be appropriate. Inter-slice forces are assumed and it is suitable for both total and

effective stress analyses of soil and rock slopes. This method is used for excavation of cuts in soil or shattered rock, since other methods which do not take into account effective stresses would generate large errors. It may also be applied to potential slip surfaces of arbitrary shape.

The Spencer method is essentially an intermediate stage between the Janbu and the Morgenstern-Price methods. It assumes parallel inter-slice forces giving fairly accurate results with a limited amount of input. The use of a computer is desirable as hand calculations become very time consuming even for simple slope geometries. The Spencer method was specifically designed for embankment stability problems, but may be used for all types of circular analyses.

The Morgenstern-Price is the most versatile method as it satisfies both force and moment equilibrium (Chowdhury, 1978). It is applicable to failure surfaces of arbitrary shape and arbitrary boundary conditions, but the use of a computer is essential. Since the output is only as good as the input, an extensive testing and monitoring system is required to warrant the use of this method. The Morgenster-Price method is generally used in situations where slope stability problems are critical.

5.1.1.1 Selection of Analysis Method

Determination of which method of limiting equilibrium analysis to use depends upon several factors such as the

homogeneity and strength properties of the slope material, expected shape of the failure surface, groundwater conditions, stratification of slope materials, and location of the potential slip plane relative to the slope face (Chowdhury, 1978). There are also several ancillary factors which affect the selection, including the degree of accuracy required, money and time allotted to the analysis, as well as the availability of computer programs, computer time, and qualified people to operate the program. For the Pit 13 area it was essential that whatever model was used it must be able to handle arbitrary shaped failure surfaces in rock slopes.

For the purposes of this study it was decided to use Janbu's Simplified Method and the Morgenstern-Price Method. Each of these analyses divides the slope into a series of slices, can be used for arbitrary-shaped failure surfaces, and is suitable for total and effective stress analyses of soil and rock slopes.

The Simplified Janbu Method does not require a digital computer as the analysis can be conducted on a hand calculator if necessary. However, a computerized version was used during this study. The more rigorous Morgenstern-Price Method was adopted in order to provide a means of comparison with results from the Simplified Janbu Method. A digital computer is mandatory for the Morgenstern-Price method and considerable expertise is required to use the method reliably and obtain valid results. Interpretation of the

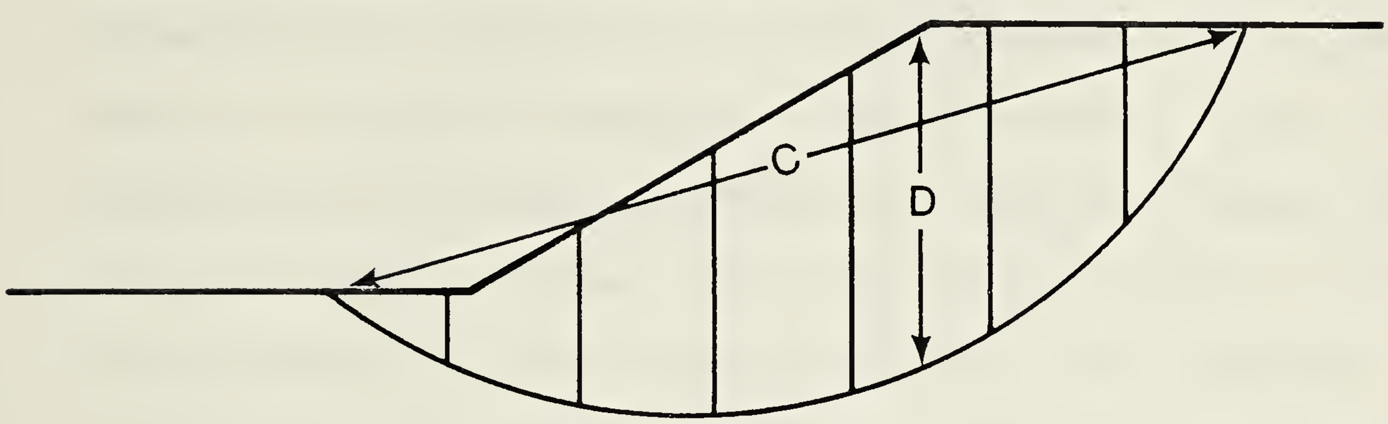
results obtained from the Morgenstern-Price Method can be difficult, and the acceptability of the solution must be checked.

5.1.1.2 Simplified Janbu Method

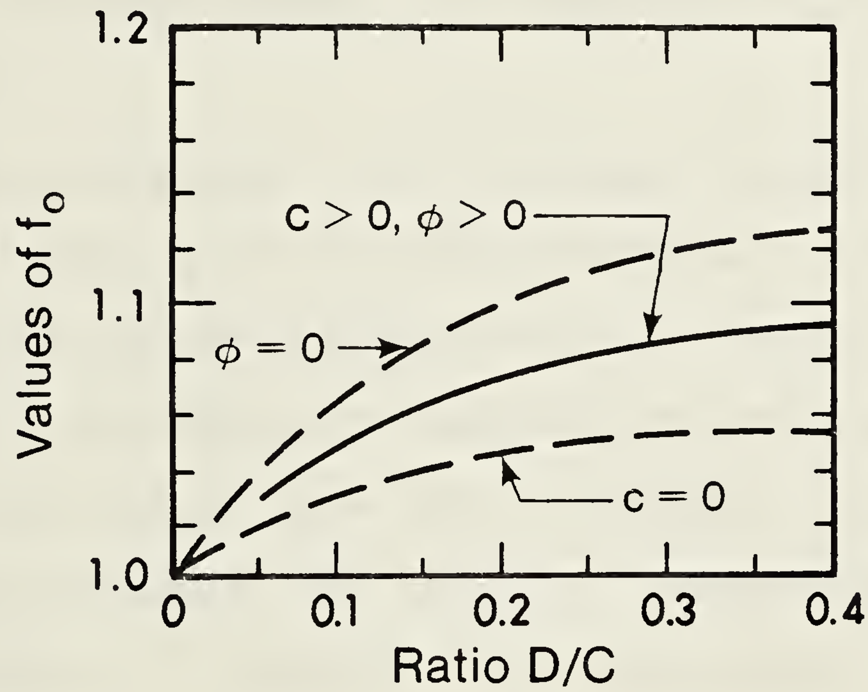
The version of the Simplified Janbu Method employed in this study is available in the Slope-II Computer Program. Slope-II is a commercial computer program package developed by Professor D.G. Fredlund and others at the University of Saskatchewan and includes both Janbu's Generalized and Simplified Mehods. Janbu's Generalized Method defines a particular location at which the interslice forces act in order to make the analysis determinant. These interslice forces are replaced by a correction factor in Janbu's Simplified Method. The correction factor is dependent upon the shape of the slip surface and the strength parameters of the slope material. The relationship between these factors is shown in Figure 13.

Care should be taken when using the Slope II version of Janbu's Simplified Method to ensure that the correction factor chosen by the program is correct. The graph from which the correction factor is chosen (Figure 13) has three lines plotted on it. The top and bottom dashed lines are proposed by Janbu, depending upon the slope material shear strength parameters. However, the center line is used in the Slope II analysis, regardless of the shear strength parameters. The discrepancy between correction factors is

Correction Factors for Janbu's Simplified Method



"D" Distance Used in Slope – II Program



Janbu's Simplified Method Correction Factor, f_o

(After Slope – II, Slope Stability Analysis Users Manual)

FIGURE 13

greater for analyses conducted in cohesionless slope materials. It is further exagerated because the D value used in the Slope II package is taken as the vertical distance from the slope crest to the failure plane, rather than the perpendicular distance from the slope face as proposed in Janbu's original analysis. As a result, the D/C ratio assumed by the Slope II version is slightly larger than the correct value. Since the correction factor is directly proportional to the overall Factor of Safety, these variations in the Slope II program can generate a substantial error, especially in designs involving deep seated failure planes in materials with little or no cohesion.

Upon selection of the proper correction factors, the overall Factor of Safety of the failure surface is easily calculated as convergence is quite rapid (Chowdhury, 1978). The Factor of Safety in this analysis can be defined as the factor by which the shear strength parameters must be reduced in order to satisfy conditions of limiting equilibrium. It should also be noted that the Slope-II program requires all failure surfaces to be represented by slip circles. However, failure may be forced along a weakness plane in the Slope-II version of Janbu's Simplified Method by designating the underlying rock's strength parameters as extremely large.

5.1.1.3 Morgenstern-Price Method

The version of the Morgenstern-Price analysis used in this study was obtained from the Department of Civil Engineering at the University of Alberta. The analysis is rendered statically determinant by assuming a relationship between the effective normal thrust and the shear force acting on a vertical interface. It should be noted that not all versions use the effective side stress assumption but instead are expressed in terms of total stresses.

The relationship between the effective normal and shear interslice forces is given by a function selected by the user which defines the variation of these faces throughout the potential sliding mass (Documentation of Limit Equilibrium Analysis of Slope Stability by Morgerstern-Price Method). The value of the side force function for each slice is interpolated by the program. The interpolation is derived from values assigned to selected points along the failure surface. This is referred to as a specified side force function although other types of functions may be assumed by other programs. The types of functions most often used includes constant, linear, half-sine, clipped-sine, or trapezoidal.

For most cases, the specified function type is started with all values constant and equal to one. This implies parallel inter-slice forces and is generally satisfactory (Chowdhury, 1978). Special cases, such as slopes containing high water pressures, may require different side force

function assumptions in order for the Method to produce acceptable results.

The solutions obtained from the Morgenstern-Price Method must be checked to see if they are physically feasible. There must be a reasonable distribution of the normal stresses acting on each potential failure surface. A reasonable distribution is obtained by choosing an appropriate side force function.

Chowdhury (1978) summarized some general guidelines for determining admissable solutions with the Morgenstern-Price Method:

1. The interslice boundaries must not contain effective tensile stresses. This requirement may not have to be rigorously applied near the crest of the slope.
2. The local shear strength or failure criterion must not be reached within the potential failure mass.

Chowdhury (1978) also states that these guidelines need not be as strictly adhered to in the case of rock slopes.

The solutions obtained using the Morgernstern-Price Method are not unique, but the variations in the overall Factor of Safetey is not significant. In some cases, solutions which do not satisfy the admissability criterion may still provide valid results. Consequently, discretion is required in determining the acceptability of the solutions.

5.2 Determination of Rock Mass Strength Parameters

Experience elsewhere in the Mynheer A mining zone has shown that failures in the proposed Pit 13 walls will probably occur in a deep seated block failure. Shallow seated, circular slip failures do occur in the study area, but only on the badly weathered walls of the old mine workings. It is unlikely that such failures will occur during the predicted life span of Pit 13. In order to accurately model the deep seated block failures by means of the Simplified Janbu or Morgenstern-Price Methods, the strength properties of both the rock mass and rock discontinuities are required.

5.2.1 Estimating Rock Mass and Discontinuity Strength

Perhaps the single most critical factor in slope stability analyses is the estimation of the rock mass and discontinuity strengths. The accuracy of the estimation may be increased by laboratory testing, in situ testing, and back analysis of slope failures. However, the final selection of strength parameters is still subject to uncertainty due to sampling biases, testing inaccuracies, undetected geological features, weakness planes, etc.

There are a number of approaches used to estimate the rock mass strength parameters required for rock slope design purposes, such as the Geomechanics Classification and the Norwegian Geotechnical Instute (NGI) Classification (Q System). The Geomechanics Classification was developed in

South Africa by Bieniawski and is concerned with six separate parameters: (Barton, 1976)

1. Uniaxial compressive strength of the intact rock material.
2. Rock quality designation (RQD).
3. Joint spacing.
4. Condition of joints.
5. Groundwater conditions.
6. Joint orientation.

The NGI or Q System Classification was developed in Norway by Barton and is also concerned with six parameters: (Barton, 1976)

1. RQD.
2. Joint set number.
3. Joint roughness number.
4. Joint alteration number.
5. Joint water reduction factor.
6. Stress reduction factor.

The six parameters of the NGI Classification are used to give a rough estimate of relative block size, inter-block shear strength, and active stress. The one parameter common to both classification systems is the rock quality designation number.

While both classification systems are essentially a weighting process, it is recommended (Bieniawski, 1976) that classification approaches should be used in conjunction with other systems rather than relying on a single system. Other

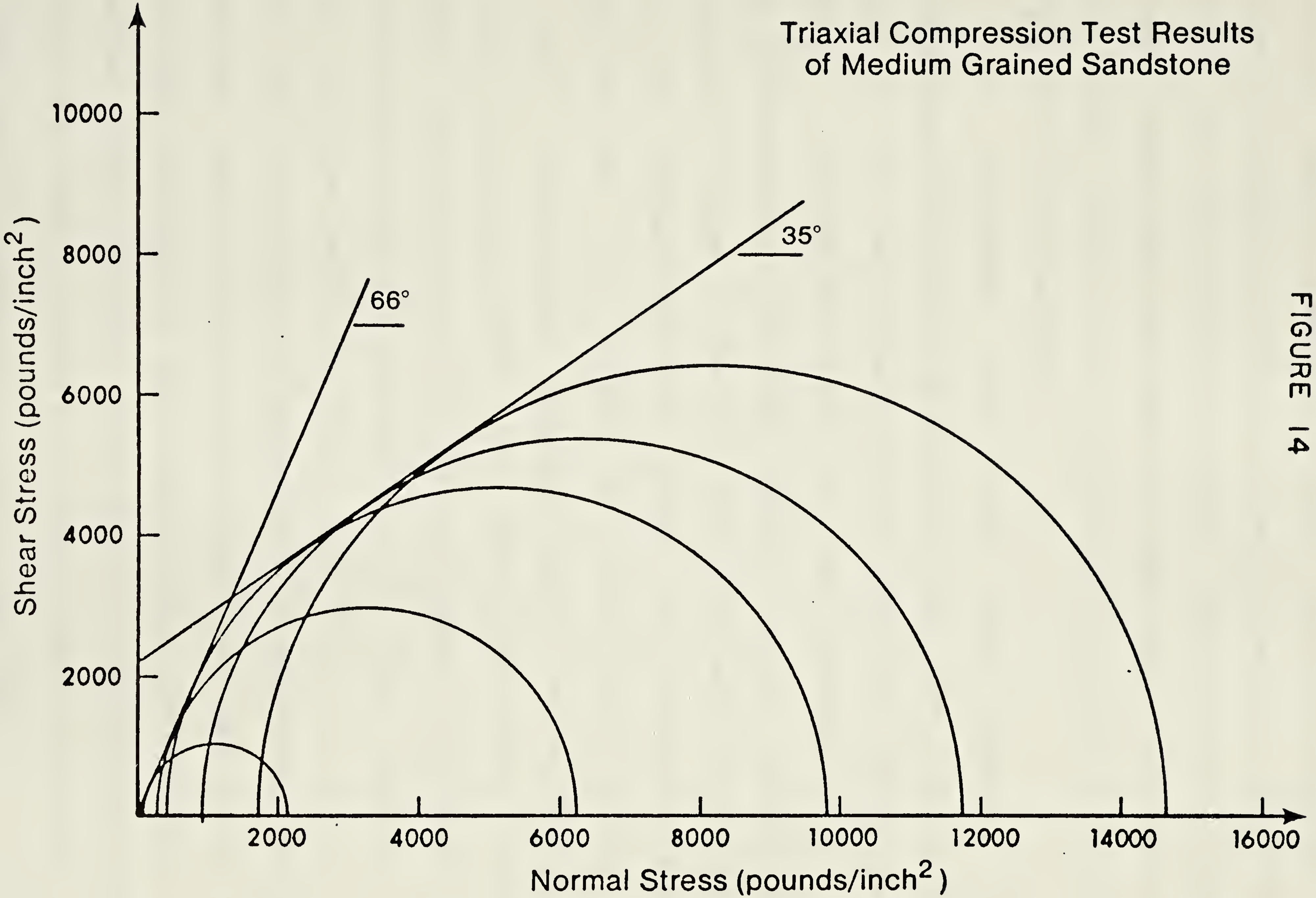
classification systems which may be used to cross-check the findings of either of the above systems includes the Wickham concept, chiefly used for steel support design, and Stimpson and Ross-Brown's system of estimating the cohesive strength of randomly jointed rock masses. (Stimpson and Ross-Brown, 1979).

5.2.2 Selection of Strengths for Coal Valley Stability Analysis

Because of its importance to the stability of the proposed pit walls, the determination of the internal friction angle of the rock mass materials was a major concern of the study. Various laboratory testing techniques, including direct shear testing of the weaker units as well as of discontinuities, and triaxial compression testing of intact rock specimens were conducted to assist in determining the shear strength parameters of the rock mass.

The triaxial testing of intact Coal Valley sandstone samples produced a curved Mohr envelope, varying from 66° to 35° over a range of confining pressures of 0 to 12.1 MPa (1750 psi)(Figure 14). It is thought that the curved failure envelope is a result of the fact that at lower confining pressures stresses are not sufficient to shear through rock irregularities and thus a higher "interlocking" friction angle results. At higher pressures shearing occurs through the intact specimen, and a lower internal friction angle is derived. Hoek and Brown (1980) suggest that the friction

FIGURE 14


Triaxial Compression Test Results
of Medium Grained Sandstone
Shear Stress (pounds/inch^2)
10000
8000
6000
4000
2000
66°
35°
2000
4000
6000
8000
10000
12000
14000
16000
Normal Stress (pounds/inch^2)

angle will vary with normal stress levels and that the friction angle parameters should be calculated for each slice in a stability analysis. However, owing to the limited height of the proposed pit walls, the variation in normal stress between the crest and the lower portions of the slope will have little or no affect on the effective friction angle of the rock material.

In accordance with Hoek and Brown's (1980) recommendations concerning slope designs, the friction angle derived from low pressure testing should be applied during the Pit 13 design due to the low normal stresses which will be encountered in the slope. However, visual examination of previous failures in the Pit 13 area indicates that shearing of the stronger rock units occurs along discontinuities in the rock mass. It is thought that these discontinuities are a result of much higher stresses than are presently incurred in the study area, and for this reason the internal friction angle derived from high confining pressure testing was used in the slope design. This decision was also based on the fact that the use of the interlocking friction angle in both the Simplified Janbu and Morgenstern-Price Methods predicted shallow seated failure planes rather than deep seated block failures. In order to more accurately simulate the deep seated block failures experienced in the Mynheer A mining zone, the lower internal friction angle resulting from higher pressure compression testing was used.

In order to estimate a value for rock mass cohesion of the slope materials, a back analysis and sensitivity analysis was conducted on a failure zone in the adjacent Pit 14 mining area (Photo 2). The back analysis was completed using the Simplified Janbu Limiting Equilibrium Method. The slope geometry, structural geology, and assumed groundwater conditions in the failure zone are illustrated in Figure 15. The material directly above the failure surface was assumed to be sandstone. A range of values of cohesion was inserted into the limiting equilibrium analysis and the overall factor of safety determined. A graph of the relationship between cohesion and overall Factor of Safety is plotted in Figure 16. With a friction angle of 35°, the cohesion required to give a factor of safety of 1.0 is 0.040 MPa (900 lb/ft^2).

The same technique was attempted on a stable area immediately adjacent to the failed sector, and the analysis indicated that the wall was stable even when the material was assumed to have no cohesion. As a result, no lower bound was found for the rock mass cohesion.

For the stability analysis of Pit 13, a cohesion value of 0.040 MPa (900 lb/ft^2) was used for the sandstone. This is the upper bound for cohesion determined from the back analysis. It should be noted that for the analysis the entire strata sequence was assumed to be composed of sandstone but in reality there are interbedded siltstones and silty mudstones above the Lower Mynheer. However, since

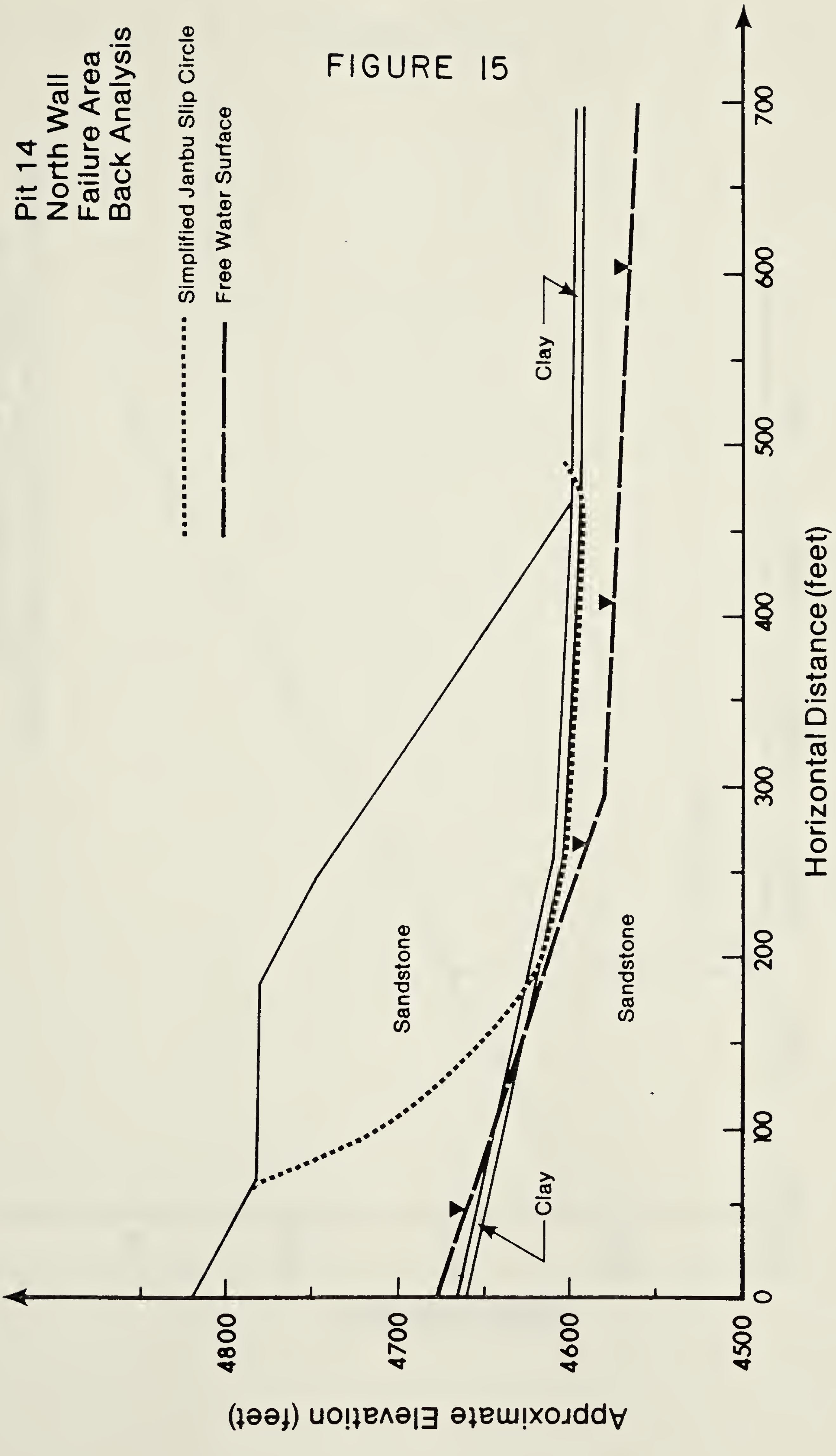
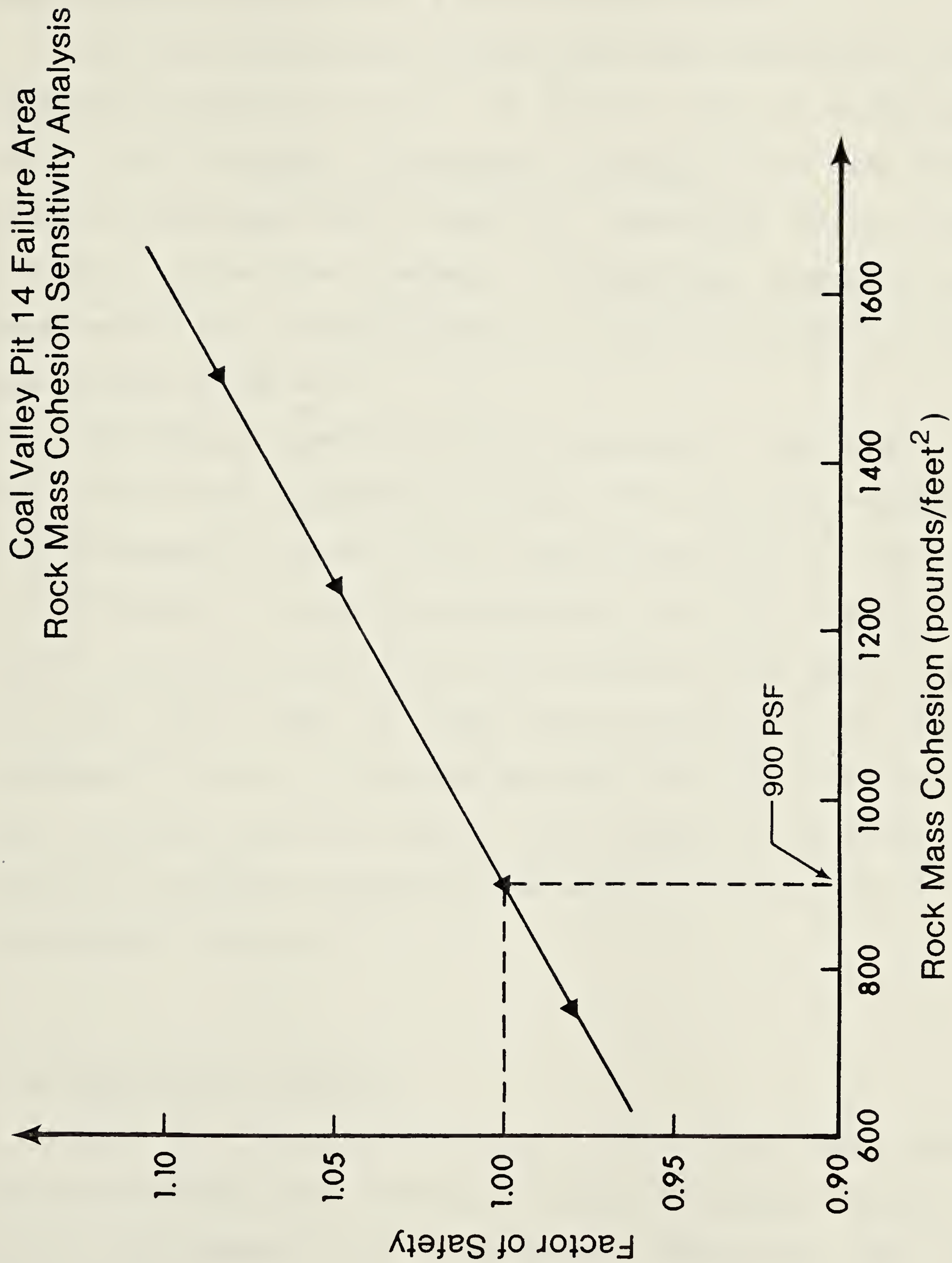

Pit 14
North Wall
Failure Area
Back Analysis
Simplified Janbu Slip Circle
Free Water Surface
Sandstone
Sandstone
Clay
Clay
Approximate Elevation (feet)
4500
4600
4700
4800
Horizontal Distance (feet)
0
100
200
300
400
500
600
700

FIGURE 15

FIGURE 16


Coal Valley Pit 14 Failure Area
Rock Mass Cohesion Sensitivity Analysis
Factor of Safety
1.10
1.05
1.00
0.95
0.90
600
800
1000
1200
1400
1600
900 PSF
Rock Mass Cohesion (pounds/feet2)

the sandstone had the highest friction angle of any of the materials tested, the cohesion value determined from the back analysis would be of a conservative nature.

For final estimation of the rock mass properties it was decided to separate the Pit 13 strata into 9 individual units. The strength properties inserted into the final stability analyses were a result of laboratory testing, back analysis, literature reviews, engineering judgement, and experience. The values assigned to each lithological unit are listed in Table 5.

Groundwater conditions were selected on the basis of the data from piezometers 2192, 2193, and 2194 augmented with piezometric levels from holes recently drilled for installation of slope inclinometers in the Pit 14 area. The general conclusions derived from the dewatering study in Pit 14 were also used in the determination of the Pit 13 piezometric levels. It should be noted that any increase in the phreatic surface above that assumed in the stability analysis would have adverse consequences on the stability of the overall pit walls.

5.3 Comparison of Results

Both the Morgenstern-Price and Simplified Janbu Analysis Methods were conducted in each Geological Sector in Pit 13. The geometry and groundwater conditions used for each Sector are illustrated in Figures 17 through 20.

TABLE 5

ROCK MASS STRENTH PARAMETERS

Lithology	Unit Weight Kg/m³	Unit Weight lb/ft³	Effective Cohesion MPa	Effective Cohesion lb/ft²	Effective Friction Angle[1] degrees
Bentonitic Clay	1922	120	0.0	0.0	8.5
Bentonitic Mudstone	1922	120	0.0	0.0	20.5
Silty Mudstone	2002	125	.036	800	32.0
Siltstone	2002	125	.038	800	34.0
Sandstone	2082	130	.040	900	35.0
Lower Mynheer Coal Seam	1442	90	0.0	0.0	10.5
Upper Mynheer Coal Seam	1442	90	.014	300	30.0
Fault Zone (Broken Siltstone)	2002	125	0.0	0.0	25.0
Interlayered Mudstone-Siltstone	2002	125	.036	800	33.0

[1]Taken parallel to bedding.

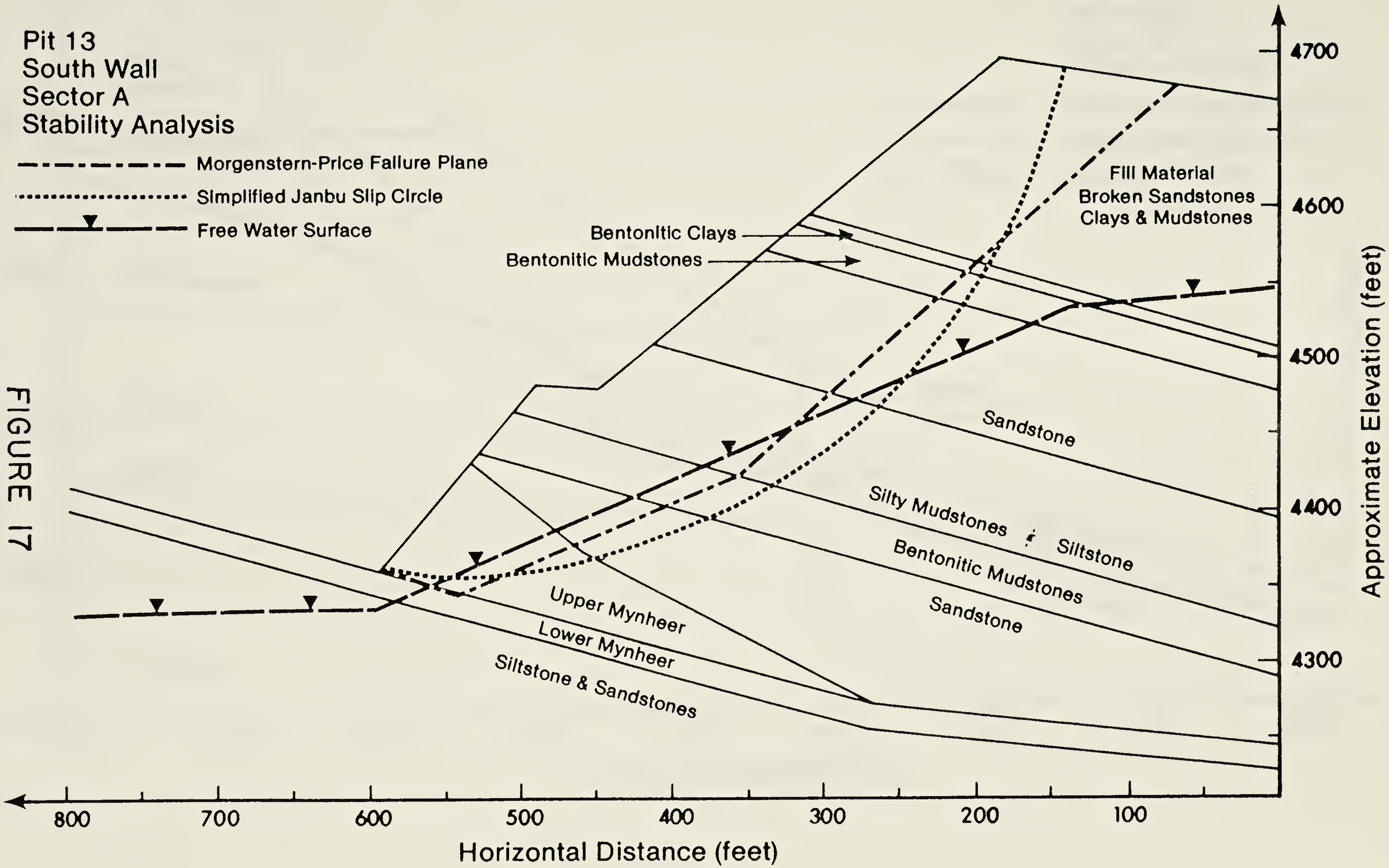
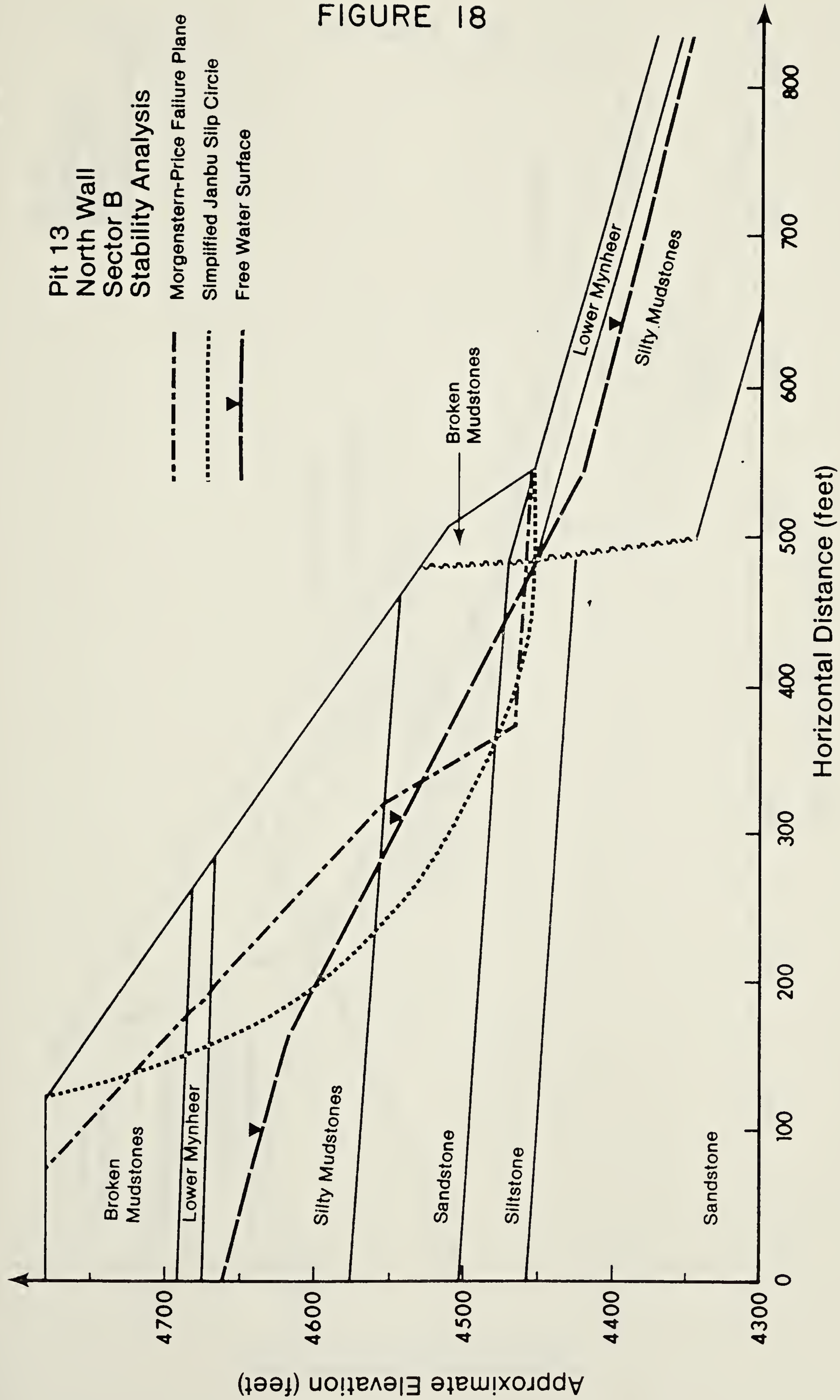

Pit 13
South Wall
Sector A
Stability Analysis
Morgenstern-Price Failure Plane
Simplified Janbu Slip Circle
Free Water Surface
Fill Material
Broken Sandstones
Clays & Mudstones
Bentonitic Clays
Bentonitic Mudstones
Sandstone
Silty Mudstones & Siltstone
Bentonitic Mudstones
Sandstone
Upper Mynheer
Lower Mynheer
Siltstone & Sandstones
4700
4600
4500
4400
4300
Approximate Elevation (feet)
800
700
600
500
400
300
200
100
Horizontal Distance (feet)

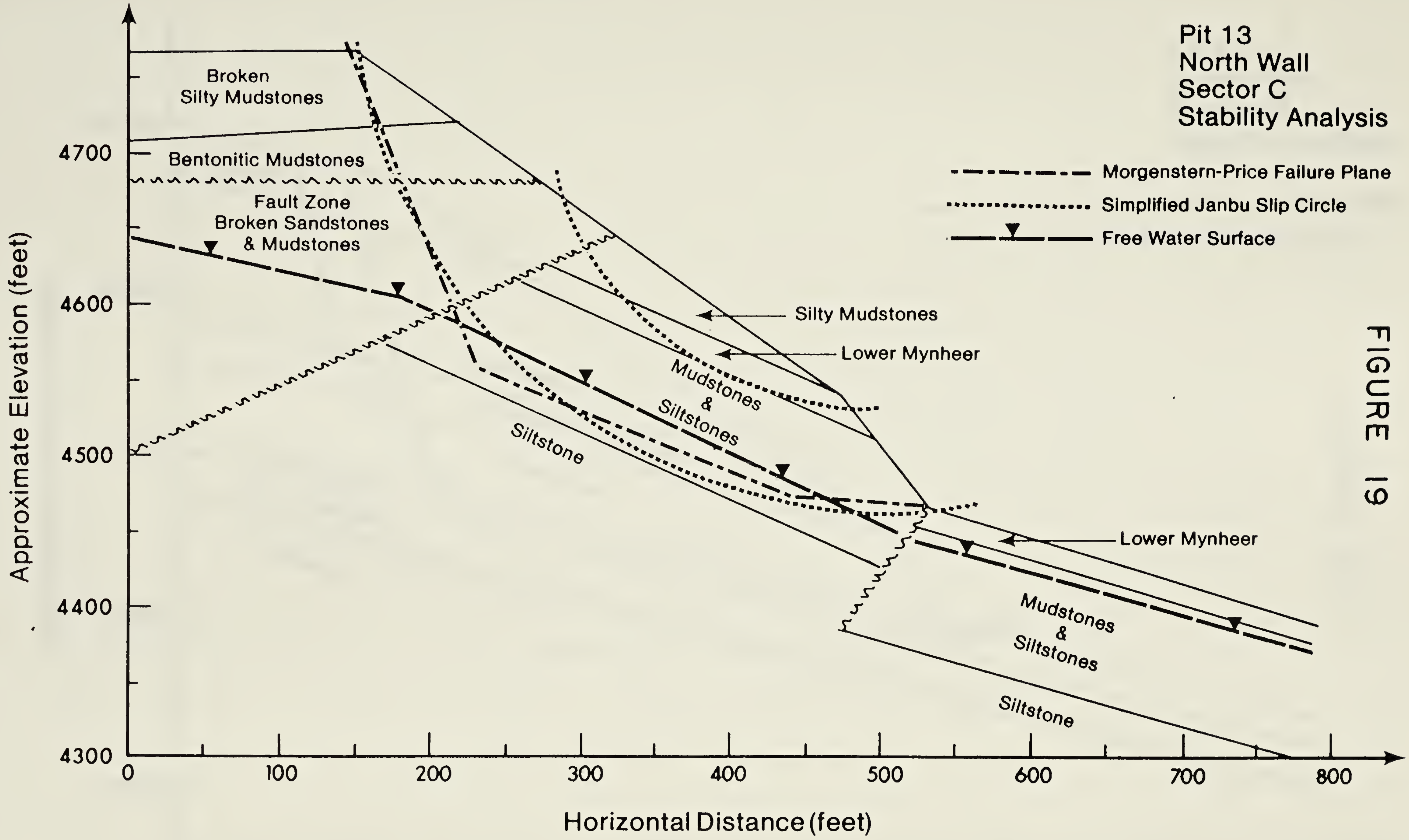
FIGURE 17

FIGURE 18



Pit 13
North Wall
Sector B
Stability Analysis
Morgenstern-Price Failure Plane
Simplified Janbu Slip Circle
Free Water Surface
Broken Mudstones
Lower Mynheer
Silty Mudstones
Sandstone
Siltstone
Sandstone
Broken Mudstones
Lower Mynheer
Silty Mudstones
Approximate Elevation (feet)
4300
4400
4500
4600
4700
Horizontal Distance (feet)
0
100
200
300
400
500
600
700
800

FIGURE 19


Pit 13
North Wall
Sector C
Stability Analysis
Morgenstern-Price Failure Plane
Simplified Janbu Slip Circle
Free Water Surface
Broken
Silty Mudstones
Bentonitic Mudstones
Fault Zone
Broken Sandstones
& Mudstones
Silty Mudstones
Lower Mynheer
Mudstones
&
Siltstones
Siltstone
Lower Mynheer
Mudstones
&
Siltstones
Siltstone
Approximate Elevation (feet)
4300
4400
4500
4600
4700
Horizontal Distance (feet)
0
100
200
300
400
500
600
700
800

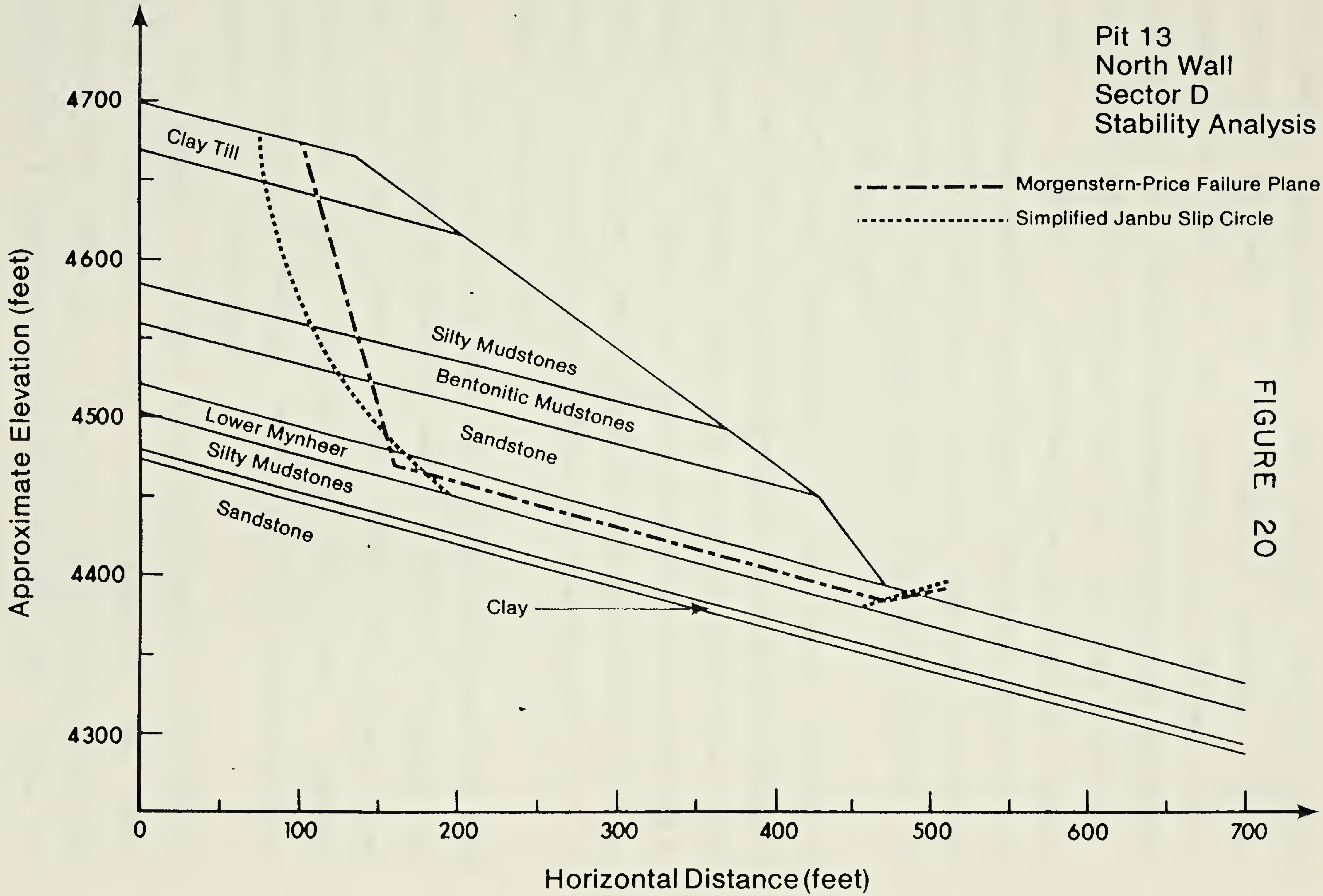

Pit 13
North Wall
Sector D
Stability Analysis
Morgenstern-Price Failure Plane
Simplified Janbu Slip Circle
Clay Till
Silty Mudstones
Bentonitic Mudstones
Sandstone
Lower Mynheer
Silty Mudstones
Sandstone
Clay
Approximate Elevation (feet)
4700
4600
4500
4400
4300
Horizontal Distance (feet)
0
100
200
300
400
500
600
700

FIGURE 20

Included in these figures is the critical failure surface determined by each of the stability methods. The wall geometry for each of the Sectors was obtained from a preliminary pit design completed by Luscar Ltd. personnel. The overall Factor of Safety obtained for each sector is given in Table 6. It should be noted that Sector D results were obtained using no pore water pressures. Due to the obvious stability problems, a special study will be required for this area to improve geological information on both the pit wall and coal pod.

As can be seen from Table 6, the overall Factor of Safety obtained from the Morgenstern-Price Method tended to be slightly greater than that of the Simplified Janbu Method. This result is consistant with work completed by Hamel in this area, who found less rigorous methods such as Bishop's to be more conservative than the Morgenstern-Price Method (Chowdhury, 1978).

Close examination of the limited data generated from this study revealed that the overall Factors of Safety for the Simplified Janbu Method does not appear over conservative when compared to the more rigorous Morgenstern-Price Method, especially for the more critical Sectors (F of S approaches 1).

In summary, it was found that Sector A would have a Factor of Safety of 1.0 with a 40° slope on the upper benches, and a 50° slope in the coal. Sector B was predicted stable with a Factor of Safety of 1.13 with 35° slopes in

----

TABLE 6

COMPARISON OF OVERALL
FACTOR OF SAFETY

LIMIT EQUILIBRIUM METHOD	SECTORS A	B	C	D
Morgenstern-Price	1.07	1.33	1.38	0.79
Simplified Janbu	1.00	1.13	1.15	0.61

----

the upper benches and 55° slopes in the coal. A similar geometry was obtained for Sector C, but local instabilities may result in some failures of the middle benches. Careful bench design, for which more detailed mapping will be required during excavation, may alleviate the problem. Sector D was found to be unstable owing to the structure and location of the Lower Mynheer in this wall, and mining may not be feasible. The seam dips into the pit in the eastern sector at approximately 15°. Lowering of the overall pit angle to stabilize the wall would probably be uneconomical. However, before such stabilizing methods as slot mining or berm construction are examined, further geologic data is required. The geologic structure of the wall rock is poorly defined at present as is the existing outline of the Upper Mynheer coal pod.

5.4 Discussion

According to Chowdhury (1978), differences in accuracy among various limiting equilibrium analyses depend largely on the type of problem. Generally speaking, where the geological aspects control the critical slip surface and can be easily predicted, the discrepancies between methods are small. Chowdhury states that, as a general rule, deep potential failure masses with high pore pressures should be analysed by relatively rigorous procedures. It is also very important to simulate real failure surfaces rather than to

approximate them with circular failure surfaces.

For the slopes studied in the Pit 13 area, the Simplified Janbu Method appears to be adequate. The inaccuracies resulting from estimation of rock mass strength properties are such that the advantages of the more rigorous analysis technique becomes negligible, since it is the accuracy of input parameters which control the accuracy of the results.

In the Pit 13 area, the presence of bentonitic clay layers within the stratigraphic sequence is a critical geotechnical factor, yet their thickness and continuity is very difficult to determine. The clays originate from bentonitic mudstones, but there is a significant difference between the strength properties of the two lithologies. The steep topography and climatic conditions accelerate the weathering process of the mudstones, producing plastic clays which play a critical role in wall stability. Since the basic geological data is somewhat speculative, a high degree of accuracy in the analysis method is is not justified.

Detection of the fine (5 cm) clay layers in the Mynheer A region is extremely difficult by any known conventional methods. Many of the mudstones in the Pit 13 area will break down immediately upon being disturbed and exposed to water. Therefore, clay layers observed in core samples may or may not be present in the undisturbed wall rock. Borehole Geophysical methods are not able to distinguish clay layers from bentonitic mudstones and hence a critical feature can

easily be undetected. Other factors such as joint continuity and infilling are difficult to quantify, yet are known to be significant in slope stability.

On the basis of the above discussion and the minor differences between the factors of safety determined by the two limiting equilibrium methods, it appears that the use of a rigorous method, such as Morgernstern-Price for slope design at Coal Valley cannot be justified for most design problems.

Although use of a computer is mandatory with the Morgenstern-Price Method, the primary additional expense in not incurred by computer costs but from the cost of obtaining the detailed input data required to warrant the use of a more rigorous and accurate stability analysis. Therefore, considerably more drilling, laboratory and in situ testing, field mapping, groundwater investigations, and sensitivity analyses would be required on the Coal Valley property than has been collected to date. For the typical mining situation and complex geology at Coal Valley, the added expense of such an increased level of investigation is not economically and technically justifiable. Consequently, it is more practicable to use slope montoring during mining to warn of impending failures or major slope movements.

6. Conclusions

The primary objective of this investigation was to analyse the stability of the overall pit walls in Pit 13. A secondary concern was to assess the NCB Cone Indenter and the use of brush platens for uniaxial compressive strength testing.

The stability study indicated that the advantages of increased accuracy of a rigorous method such as Morgenstern-Price cannot be exploited because of the lack of accurate input data. The structural geology and rock mass strength properties of most mining areas at Coal Valley are not known to the degree of accuracy required to warrant the use of the Morgenstern-Price Method. Further investigations to accurately determine strength parameters and structural features of the wall rock are generally not economically feasible.

The actual Factor of Safety predicted by the two stability models for each sector differed slightly, but both methods agreed on whether or not the overall slope for each sector would be stable.

Results of the testing program indicate that the Cone Indenter and brush platens produce strength data which agrees reasonably closely with values obtainable with conventional testing methods. The usefulness of the Cone Indenter and brush platens, especially at the feasibility stage of a geotechnical study, appears very favorable. The Cone Indenter should be of value for mapping and rock

classification purposes, for "cuttability" studies, and in the estimation of rock mass properties such as cohesion. The brush platens will make it possible to prepare and test uniaxial specimens in fragile coal measure rocks which previously has proved difficult. Further research is required to confirm the promising but preliminary results derived from these two devices.

References

Acott G.B.

Environmental Coordinator, Cardinal River Coals Ltd.

Personal Communication

February 1981

Alexander F.J.

Structural Geology of the Mynheer A Zone

M.Sc. Thesis, University of Alberta, 1977.

Atmospheric Environment

Canadian Normals 1941 - 1970 Precipitation Vol. 2-SI

Environment Canada 1975

Barton N.

Recent Experiences with the Q-System of Tunnel Support Design

Proceedings on the Symposium on Exploration for Rock Engineering

November 1976

Bieniawski Z.T.

Rock Mass Classifications in Rock Engineering

Proceedings on the Symposium on Exploration for Rock Engineering

November 1976

Broch E. and Franklin J.A.
The Point Load Strength Test
International Journal of Rock Mechanics and Mining Sciences
Vol 9 pg 669 - 697
1972

Brown E.T. and Gonano L.P.
Improved Compression Testing Technique for Soft Rock
Geotechnical Engineering Division ASCE
Vol. 100, pg 176 - 199
1974

Chowdhury R.N.
Slope Analysis, Developments in Geotechnical Engineering
Chapter 4 pg 143 - 159, Appendix III pg 394 - 399
1978

Danyluk D.M.
Report on Water Bottom Survey in the Coal Valley Area
Kenting Exploration Services Limited
1977

Dumanski J., Macyk T.M., Veauvy C.F., Lindsay J.D.
Soil Survey and Land Evaluation of the Hinton-Edson Area
Report No. 31 Alberta Soil Survey
1972

Fredlund D.G. et. al.
Slope Stability Analysis Users Manual
Department of Civil Engineering, University of Saskatchewan
April 1978.

Hillman G.R., Powell J.M., Rothwell R.L.
Hydrometeorology of the Hinton-Edson Area,
Alberta 1972 - 1975
Northern Forest Research Center Information Report NOR-X-202
March 1978

Hoek E. and Bray J.W.
Rock Slope Engineering Revised 2nd Edition
Institute of Mining and Metallurgy London England
1977

Hoek E. and Brown E.T.
Empirical Strength Criterion For Rock Masses
Journal of the Geotechnical Division ASCE Vol.106, No. GT9
September 1980

Limit Equilibrium Analysis of Slope Stability by Morgenstern-Price Method
Department of Civil Engineering, University of Alberta
October 1979

McFeat-Smith I.
Rock Property Testing for the Assessment of Tunnelling Machine Performance
Tunnels and Tunnelling
March 1977

Milligan M.F., Hebil K.E., Holmes K.W.
Report on Pit Wall Design, Pit 14 Southeast Coal Valley Mine
Internal Luscar Ltd. Report
January 1979

NCB Cone Indenter
MRDE Handbook NO. 5
1977

Neville A.M. and Kennedy J.B.
Basic Statistical Methods for Engineers and Scietists
International Textbook Company
July 1964

Stimpson B.
Design Methods in Rock Mechanics
MnlE 423 Lecture Notes
1979

Stimpson B. and Ross-Brown D.M.
Estimating the Cohesive Strength of Randomly Jointed Rock Masses
Mining Engineering SME - AIME
February 1979

Supplements 3-1 and 3-2
Laboratory Classification Tests
CANMET Pit Slope Manual
May 1977

Szlavin J.
Relationships Between Some Physical Properties of Stone Determined by Laboratory Tests
MRDE Report No. 19
March 1971

Appendix A - Description of Lithologies

The following lithologic descriptions have been excerpted from:

Milligan et. al.

Internal Luscar Ltd. Report, January 1979.

Conglomerate

Conglomerate beds range in thickness from a few inches to several feet. They are composed of rounded to subrounded, one to four inch long clasts of orthoquartzite contained in a matrix of strong to weakly cemented, medium grained arkosic sand. In places, the interstices are void of any matrix material and the clasts are loosely contained in the unit. This results in an extremely weak water bearing unit.

Sandstone

The sandstone beds range in thickness from a few feet up to one hundred feet. They are light grey in color, hard, massive, moderately fractured and arkosic in composition. Grain size varies from medium to coarse. Graded and cross-bedding textures are common. Angular to subangular grains of quartz and feldspar, mixed with fine rock fragments and dark ferromagnesian and carbonaceous materials, impart a "salt and pepper" texture to the rock. Silica and clay minerals, together with variable amounts of carbonate are the cementing agents for the sandstone. Locally, thin carbonaceous lamellae are localized in thin beds throughout the sandstones and are usually composed of recognizable plant remains. Weathering of the sandstone near the surface and throughout the unit along fractures and bedding plane partings stains the sandstone rust brown and causes local decementation of the rock to an incompetent,

[illegible]

[illegible]

[illegible]

[illegible]

sandy mass.

Siltstone

Siltstone is similar to the sandstone except for a decrease in grain size and a more variable increase in clay material content. The rock is generally more thinly laminated and is often interbedded with mudstone. The criteria used to distinguish between sandstone and siltstone has been grain size. A rock was labeled siltstone if the grain size is less than 0.3 to 0.2 mm and exhibited a relatively smooth surface. When crushed very fine, silica grit is apparent.

Mudstone

The mudstone beds vary from less than a foot to over 20 feet in thickness. Mudstone is aphanitic, medium to dark bluish grey in color and locally carbonaceous. Although locally massive and competent, the rock is usually fissile parallel to the bedding which is manifested by thin carbonaceous lamallae. Locally, decementation has reduced the rock to a platey, clay-like consistency. Mudstone is readily distinguished from siltstone by the darker gray color and aphanitic grain size. When crushed, no grit is apparent.

Clay

Clay beds vary between a few inches to one foot in thickness. The color varies from light olive green to pale gray in consistency. The beds lighten in proportion to an increase in the amount of bentonite present in the clay. Plasticity varies with the amount of silt and rock fragments present.

Coal

The Mynheer coal seams are intensely sheared and slickensided. Internal variations of the attitude of the shear planes are common. Partings and inclusions in the coal are predominantly of sandstone, a few are of a bentonitic and silty mudstone. Most are less than a few inches in diameter.

Appendix B - Testing Results

The laboratory testing results are categorized according to lithology and listed in the following sections.

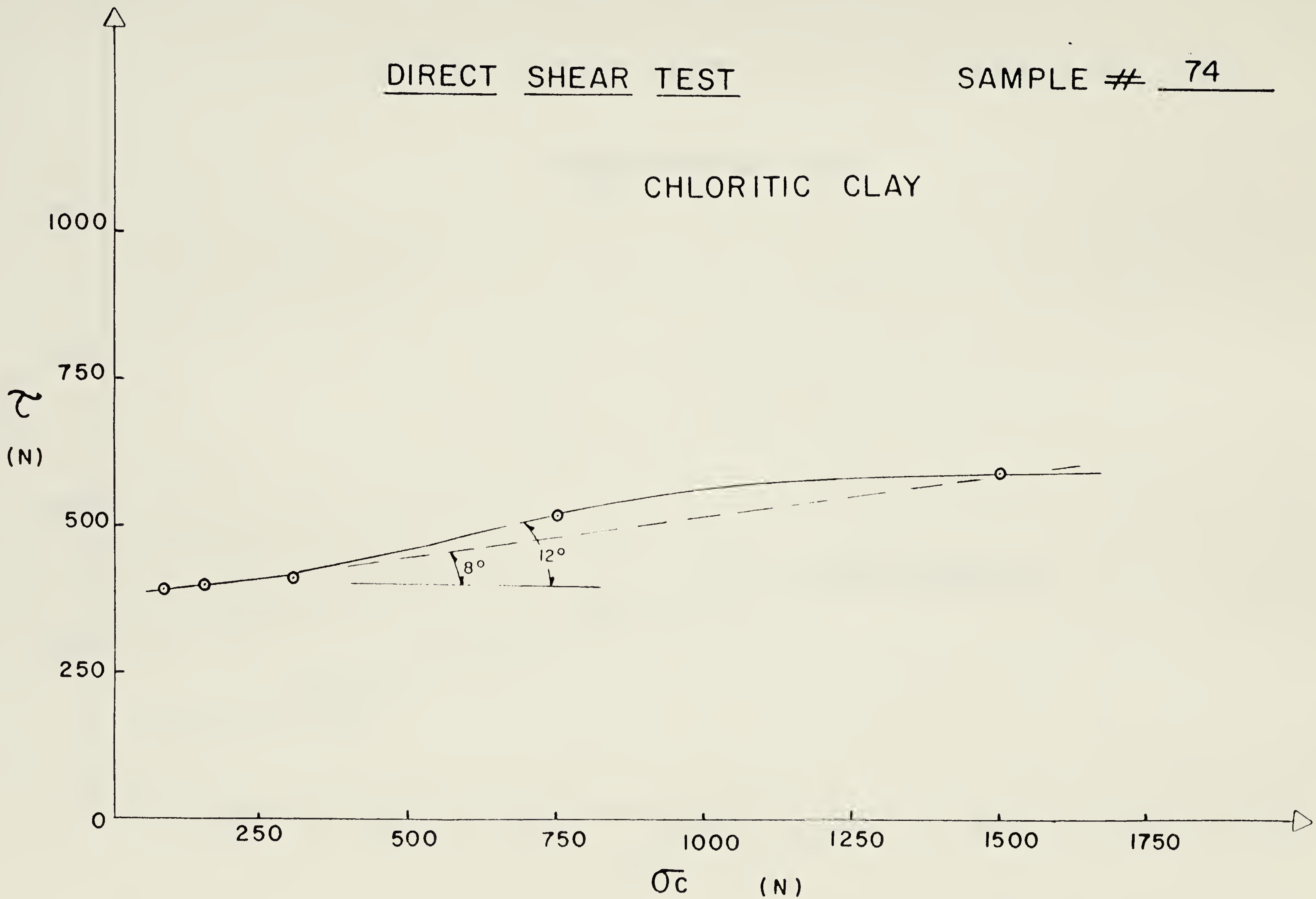
Clay

Average Sample Description

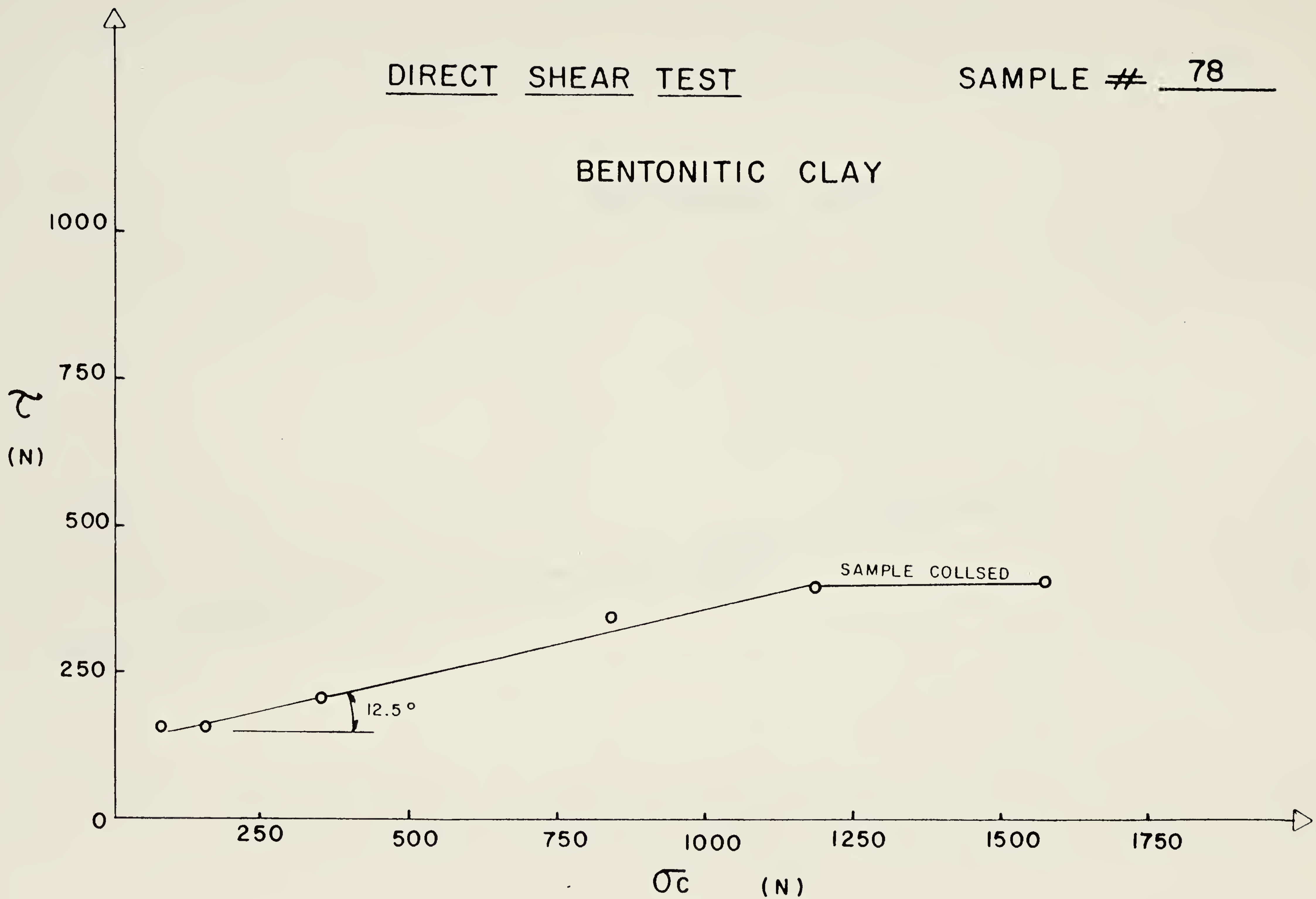
Light to medium grey bentonitic clays, chloritic samples tend to light greenish tones, carbonaceous clays range from meduim to dark grey. Generally aphanitic, sometimes gritty due to presence of very fine coal fragments. Soapy textures are frequent, especially along previous shear planes. Clays are generally cohesive, malleable, may include intermottled mudstone inclusions. Often derived from bentonitic mudstones and have been observed in outcrops to contain the original jointing systems of the mudstone.

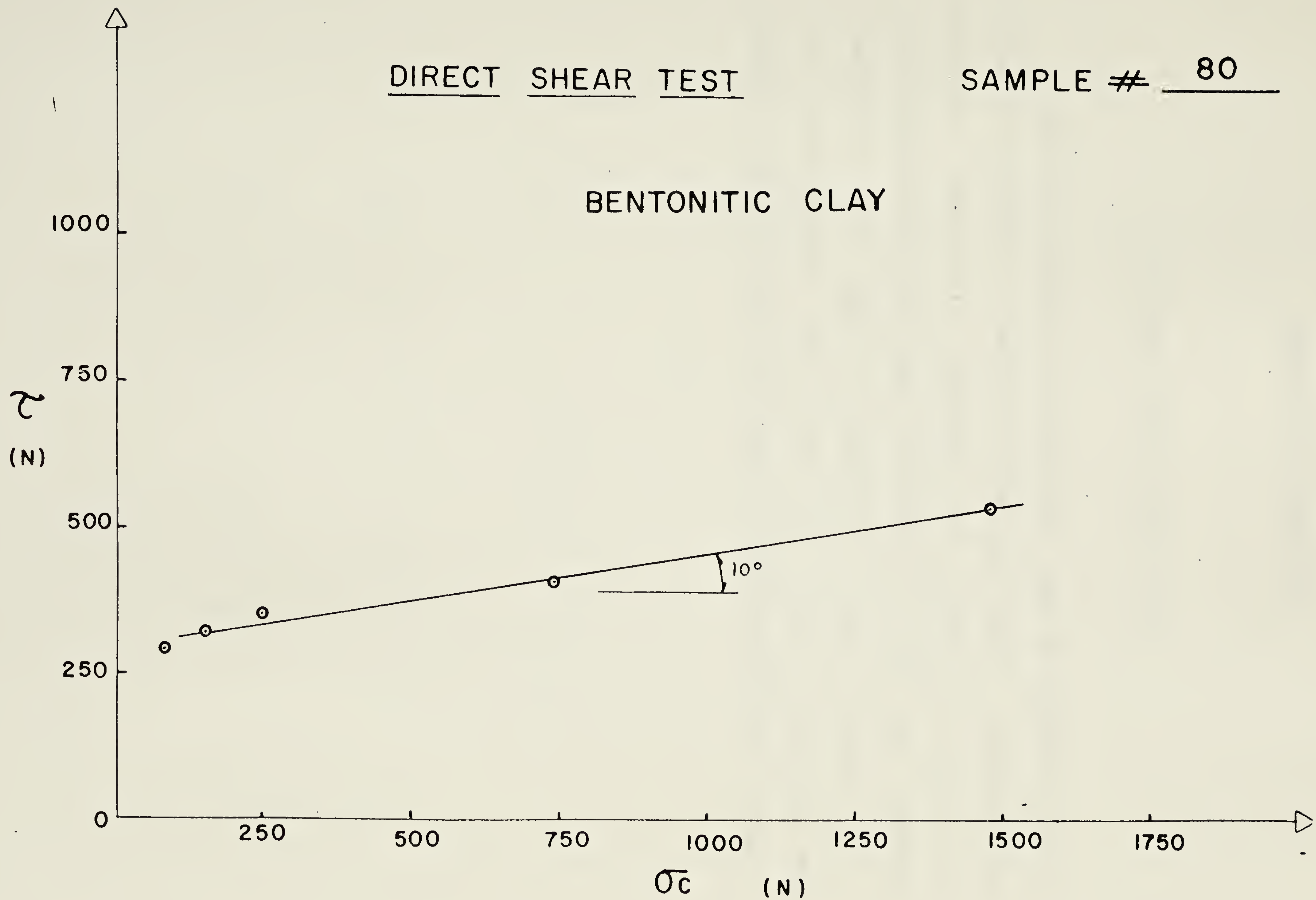
LABORATORY TEST RESULTS: CLAY

Corehole Number	Sample Number	As Received Moisture Content	Atterberg Limits		Direct Shear		
			Liquid	Plastic	Ø'p	Ør'	C' (kPa)
2193	54	27.3%	64.9%	38.6%	-	-	-
2194	74	34.6%	100.5%	46.8%	12.0°	8°	103
2194	78	-	-	-	12.5°	-	34
2194	80	9.6%	90.8%	29.8%	10.0°	-	83



DIRECT SHEAR TEST
SAMPLE # 74
CHLORITIC CLAY
τ (N)
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
σc (N)
8°
12°


DIRECT SHEAR TEST
SAMPLE # 78
BENTONITIC CLAY
τ (N)
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
σc (N)
12.5°
SAMPLE COLLSED



DIRECT SHEAR TEST
SAMPLE # 80
BENTONITIC CLAY
τ
(N)
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
σc (N)
10°

Bentonitic Mudstone

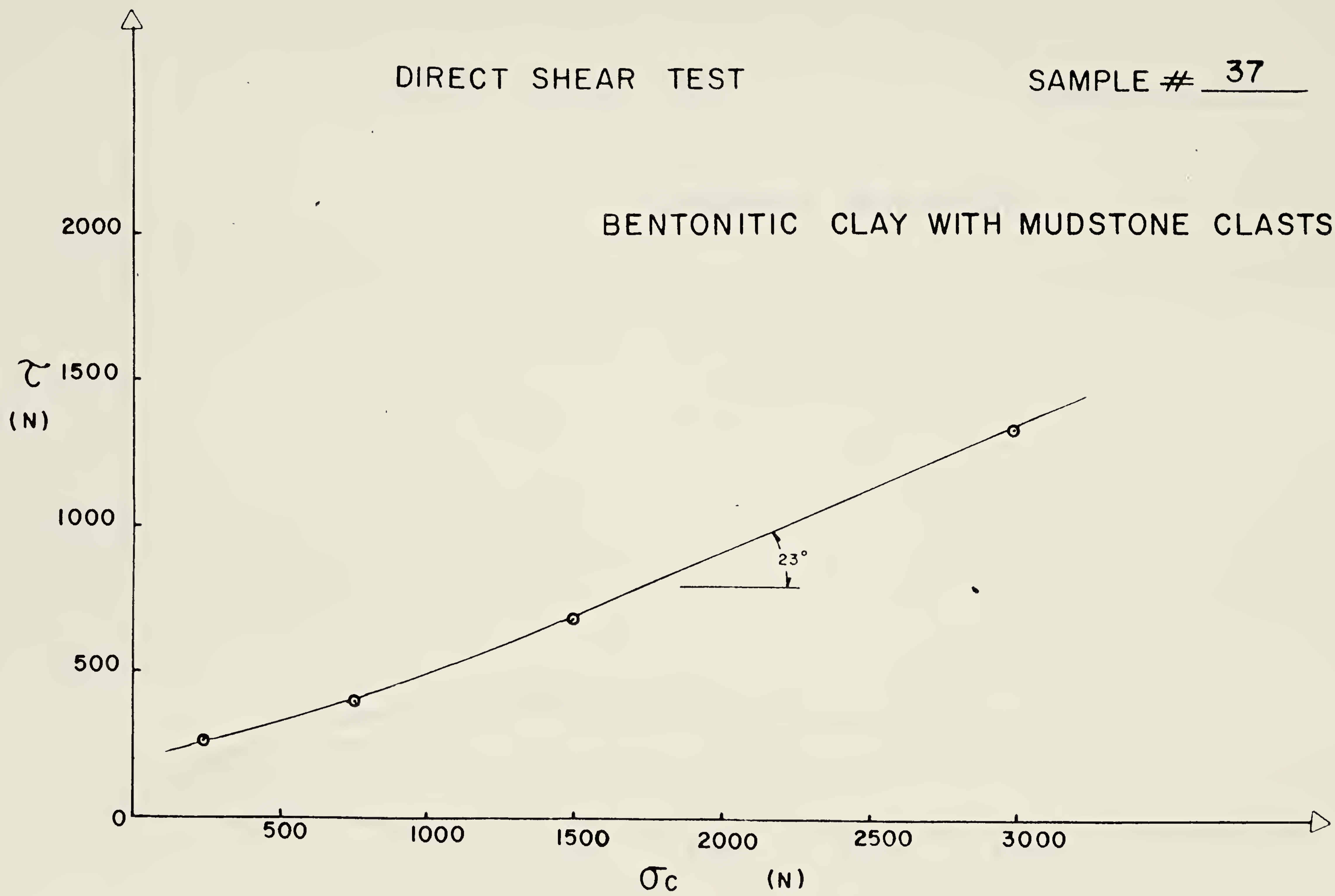
Average Sample Description

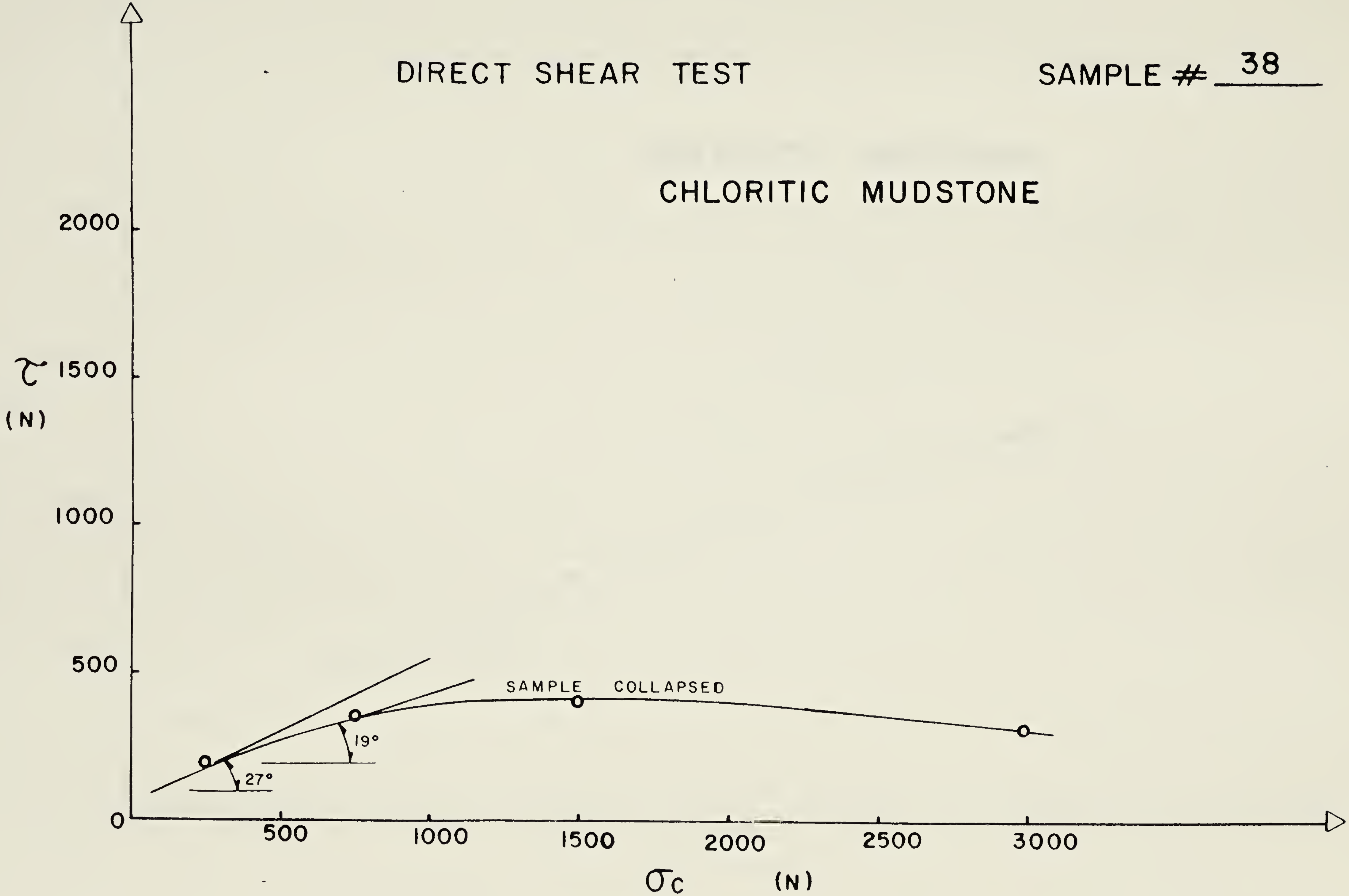
Light grey bentonitic mudstones, may be greenish due to chloritic content or range to dark grey due to carbonaceous material. Bentonitic mudstones are generally aphanitic, often associated with clays. Perimeter of the core samples frequently broke down to bentonitic clays, interior still intact and exhibits rock qualities. Often fractured and sheared, contain highly polished slickensided shear planes.

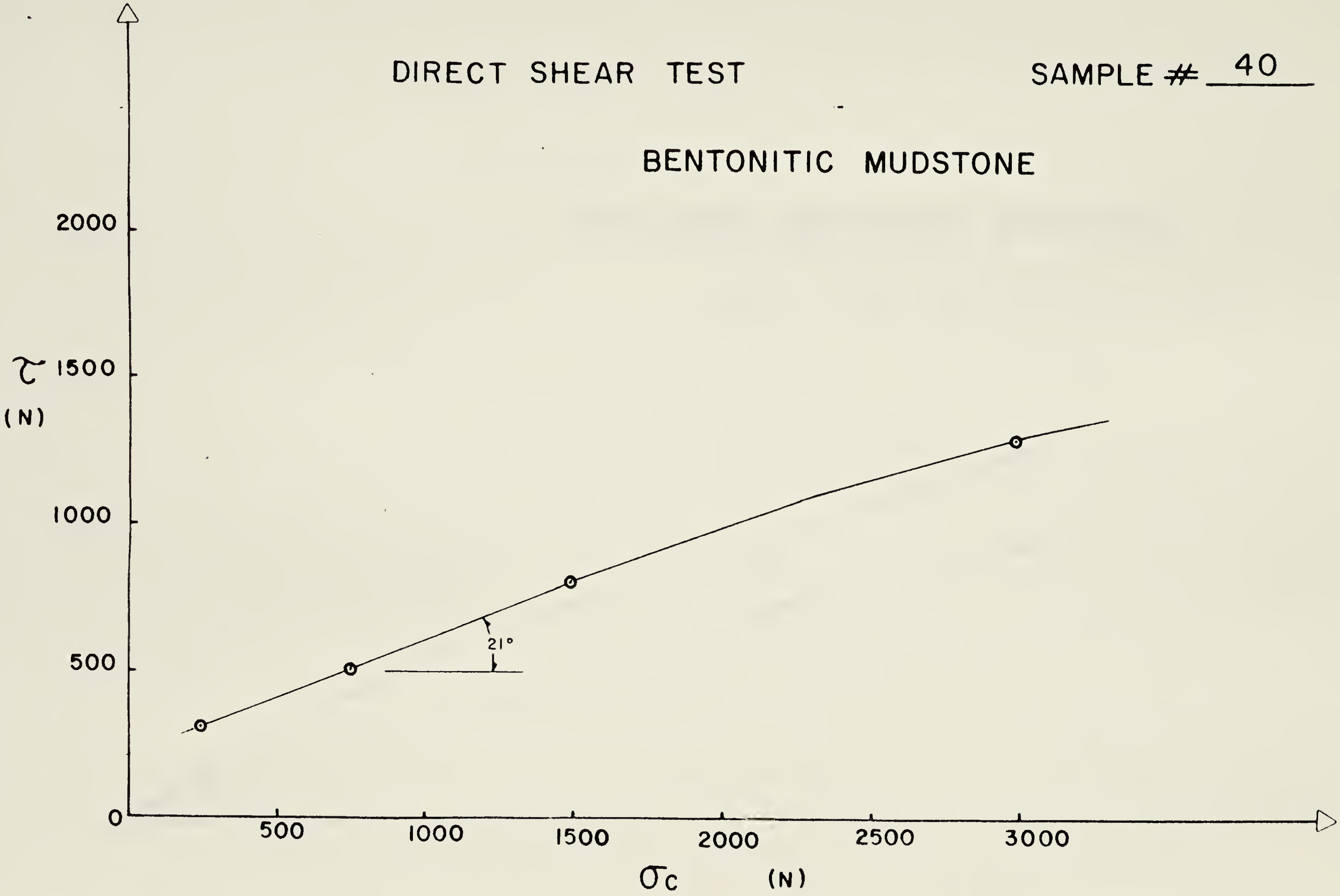
LABORATORY TEST RESULTS: BENTONITIC MUDSTONE

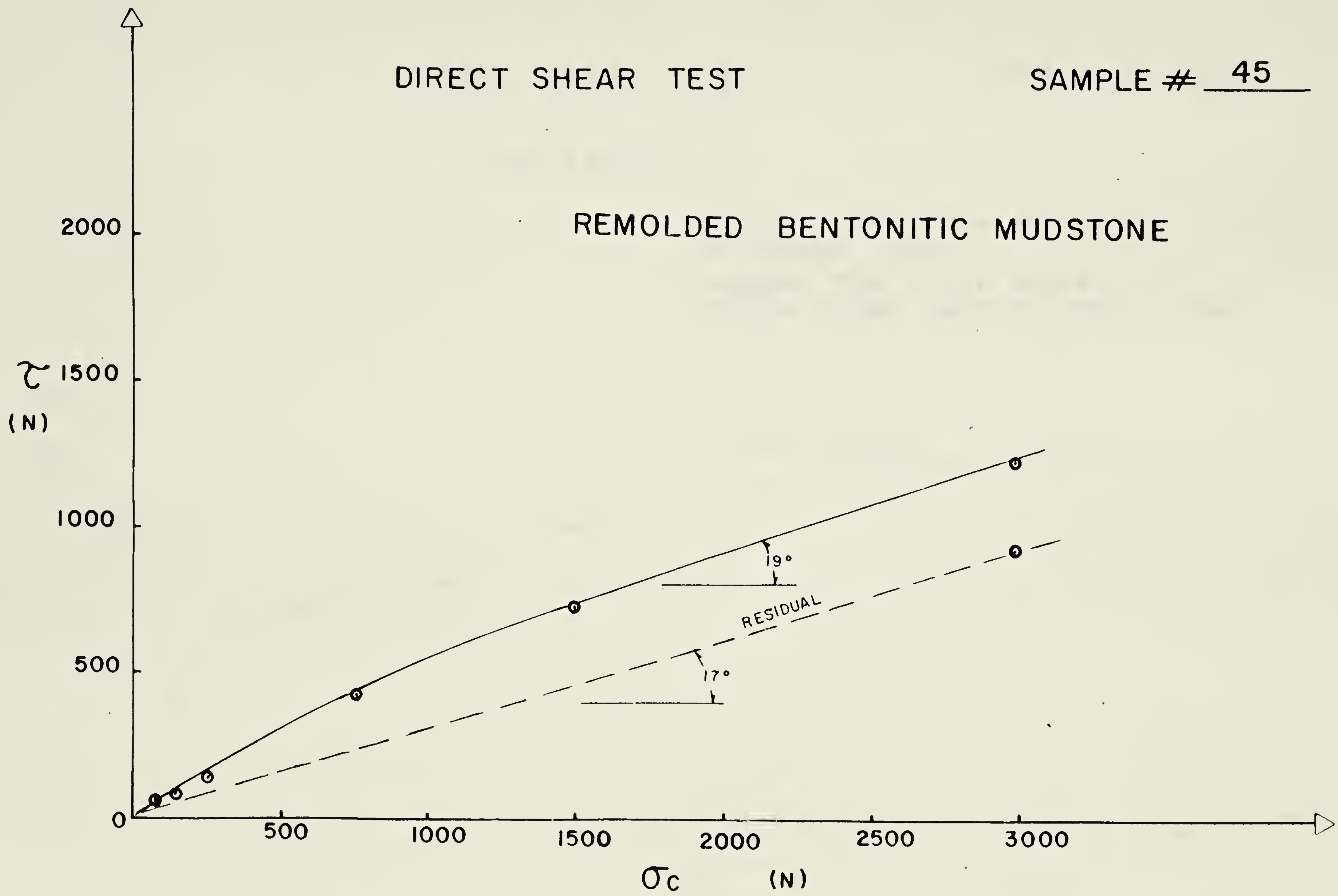
Corehole Number	Sample Number	As Received Moisture Content	24 Hour Water Absorption	Direct Shear		
				Ø'p	Ø'r	C' (kPa)
2192	37	-	-	23°	-	55
2192	38	-	-	27°	19°	21
2192	40	-	-	21°	-	55
2192	42	7.1%	-	-	-	-
2192	43	7.5%	-	-	-	-
2192	45*	19.5%	-	19°	17°	0
2192	46	38.8%	-	-	17°	34
2192	48	15.4%	-	-	-	-
2192	49	4.9%	0.14%	-	-	-
2193	56	19.4%	-	-	-	-
2193	57	16.2%	-	18°	-	26
2193	60	14.0%	-	-	-	-

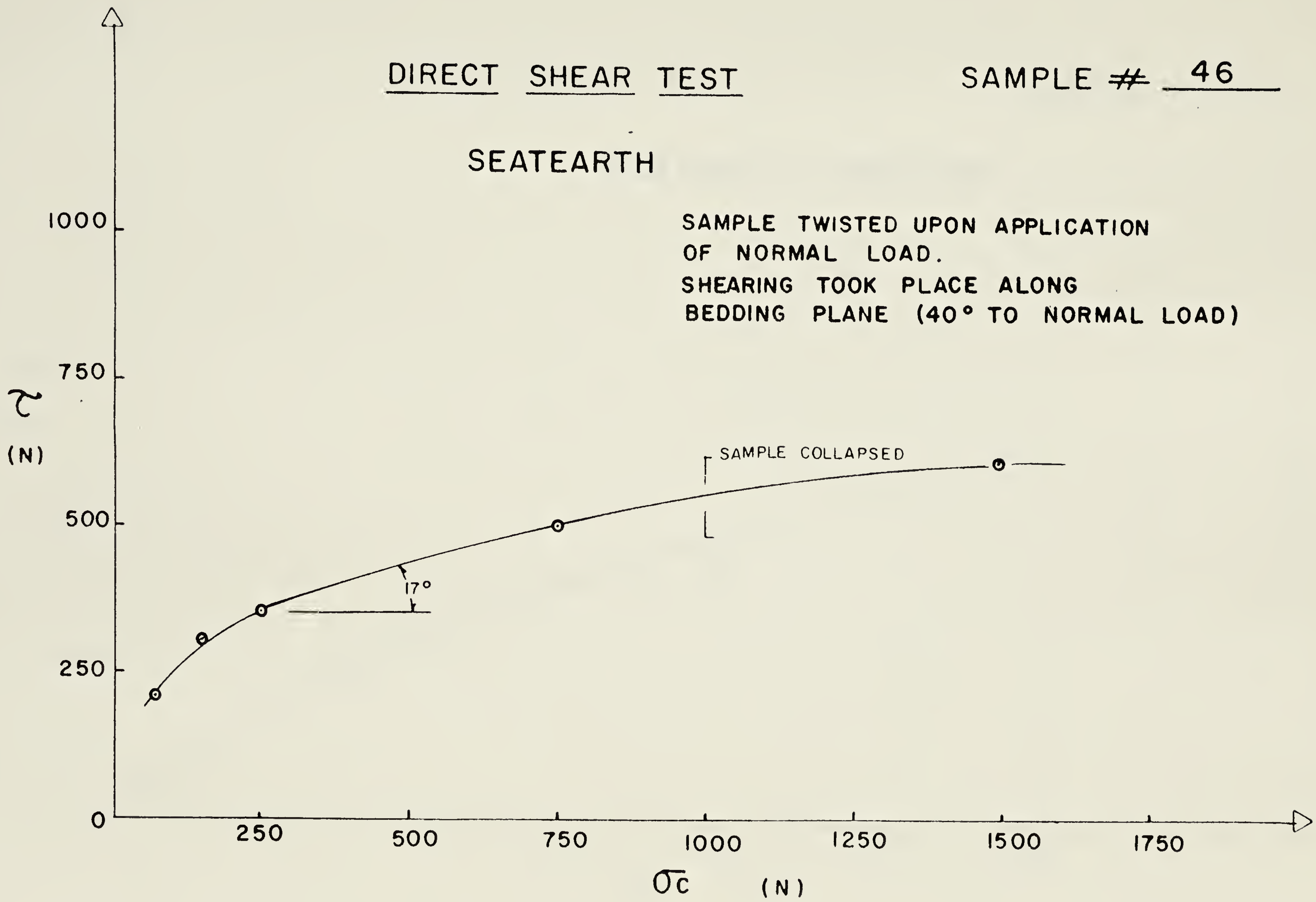
* Remolded Sample

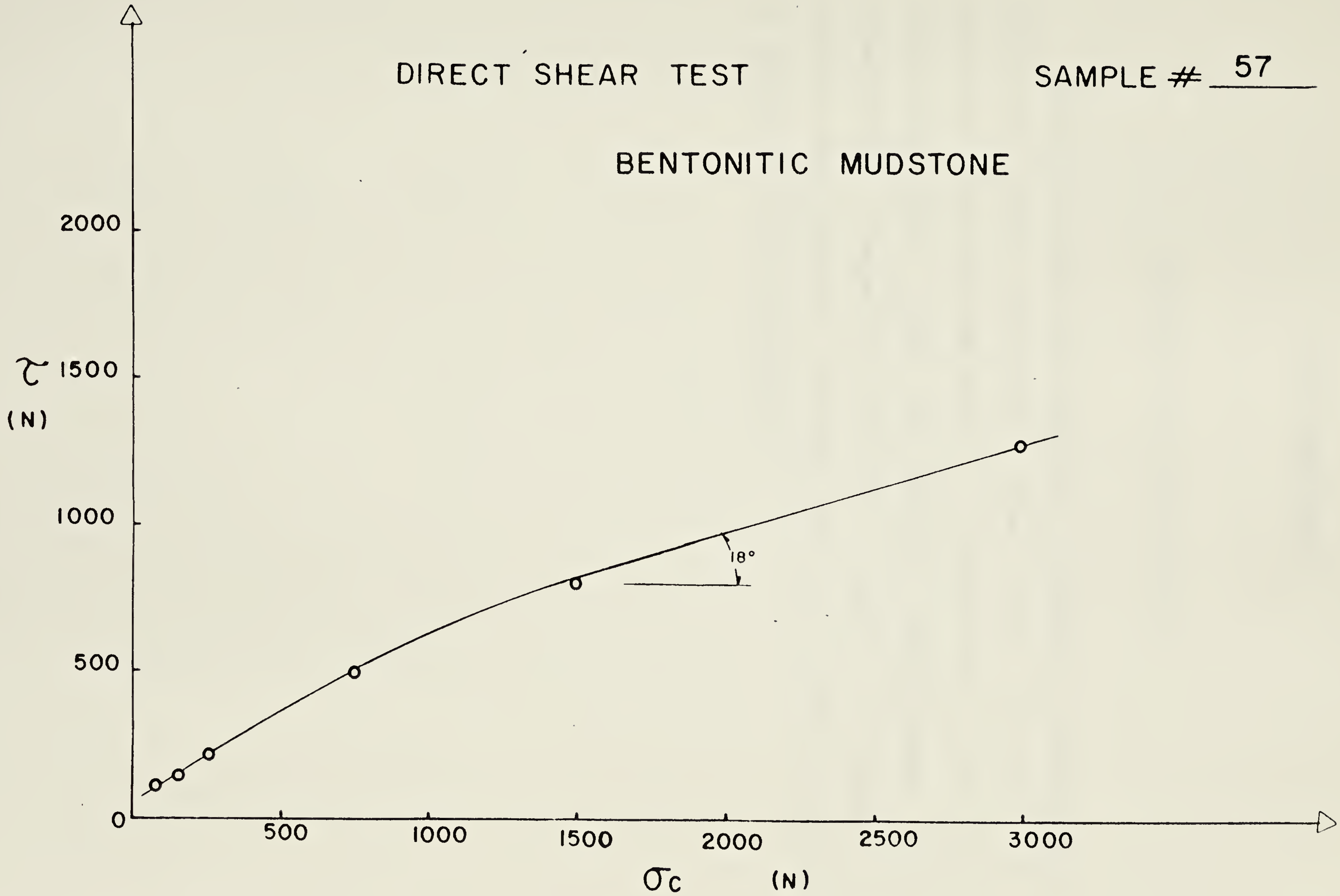

DIRECT SHEAR TEST
SAMPLE # 37
BENTONITIC CLAY WITH MUDSTONE CLASTS
τ (N)
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
σc (N)
23°


DIRECT SHEAR TEST
SAMPLE # 38
CHLORITIC MUDSTONE
τ (N)
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
σc (N)
SAMPLE COLLAPSED
27°
19°


DIRECT SHEAR TEST
SAMPLE # 40
BENTONITIC MUDSTONE
τ (N)
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
σc (N)
21°


DIRECT SHEAR TEST
SAMPLE # 45
REMOLDED BENTONITIC MUDSTONE
τ (N)
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
σc (N)
19°
17°
RESIDUAL


DIRECT SHEAR TEST
SAMPLE # 46
SEATEARTH
SAMPLE TWISTED UPON APPLICATION OF NORMAL LOAD.
SHEARING TOOK PLACE ALONG BEDDING PLANE (40° TO NORMAL LOAD)
SAMPLE COLLAPSED
17°
τ (N)
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
σc (N)


DIRECT SHEAR TEST
SAMPLE # 57
BENTONITIC MUDSTONE
τ (N)
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
σc (N)
18°

Silty Mudstones

Average Sample Description

Medium to dark grey mudstones, frequently carbonaceous containing coaly inclusions. Often silty, but may be aphanitic. Name derived from it's similarities to siltstone rather than grain size. May contain cobble-shaped clay interclasts, frequently chloritic. Samples are generally cohesive and competent, although jointing is common. Bedding is generally indistinguishable.

LABORATORY TEST RESULTS: SILTY MUDSTONE

Corehole Number	Sample Number	As Received Moisture Content	Brazilian Disc (MPa)	Cone Indenter (CI#)	Cone Indenter (MPa)†	Uniaxial Compressive Strength Solid Platen
2193	61		1.34*	0.62	12.2	
2193	64		1.47	0.73	17.2	
2193	65	15.7%				
2193	67	8.0%		0.52	7.7	11.4
2193	69	9.7%		1.67	59.8	

* Tested parallel to bedding
† Derived from the relation $\sigma_c = 45.3\ (CI\#) - 15.9$

Siltstone

Average Sample Description

Medium grey siltstone, often greenish due to chloritic content, generally very fine grained. Siltstones often contain carbonaceous nodules and laminations, useful for distinguishing bedding. Calcareous cementation, generally cohesive. Siltstones are frequently jointed, exhibiting lustrous shear surfaces, generally planar.

LABORATORY TEST RESULTS: SILTSTONE

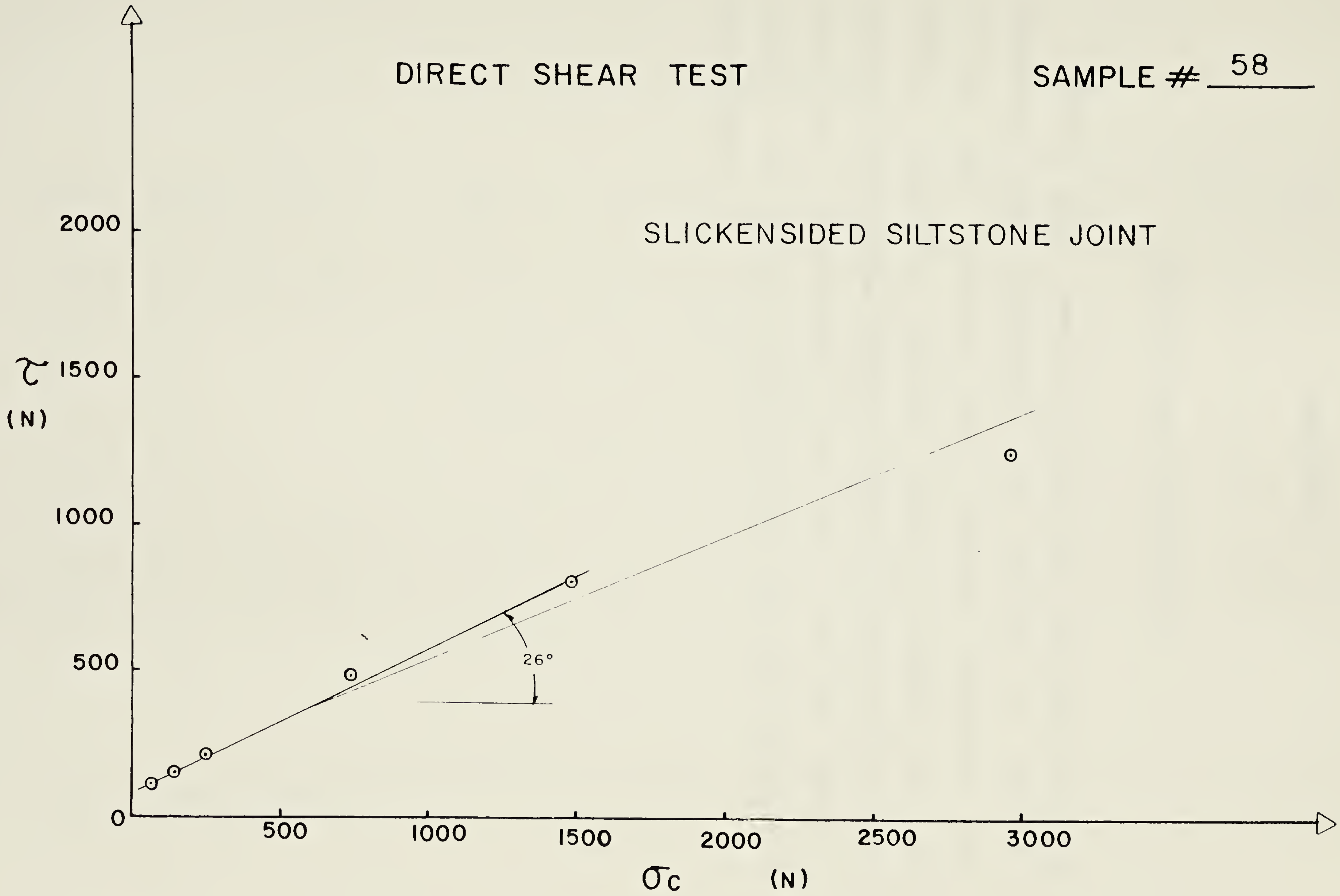
Corehole Number	Sample Number	As Received Moisture Content	24 Hour Water Absorption	Direct Shear		Brazilian Disc	Cone Indenter		Uniaxial Compressive Strength
				Ø'r	C' (kPa)	(MPa)	(CI#)	(MPa)†	Solid Platens (MPa)
2192	41	6.3	-	-	-	-	-	-	-
2192	47	5.8	0.15	-	-	-	-	-	-
2192	48	6.0	-	-	-	-	-	-	-
2192	50	8.1	-	-	-	1.71	0.82	21.2	-
2193	58	7.3	-	26*	27.5	-	-	-	-
2193	62	6.6	-	-	-	-	0.96	27.6	18.7
2193	70	17.0	-	-	-	-	0.69	15.4	-
2193	71	10.8	-	-	-	0.63	0.62	12.2	-
2194	77	7.1	-	-	-	1.90	1.06	32.1	-
2194	79	18.2	-	-	-	-	0.81	20.8	-
2194	82	6.5	-	-	-	-	-	-	-
2194	83	6.9	-	-	-	1.43	0.78	19.4	-

* Calcite joint
† Derived from the relation $\sigma_c = 45.3\ (CI\#) - 15.9$

LABORATORY TEST RESULTS: SILTSTONE

Corehole Number	Sample Number	As Received Moisture Content	Brazilian Disc (MPa)	Cone Indenter (CI#)	Cone Indenter (MPa)*	Uniaxial Compressive Strength: Solid Platen (MPa)	Uniaxial Compressive Strength: Brush Platen (MPa)	Uniaxial Compressive Strength: Angle of Break To Core Axis
2194	85	6.6%	0.67††	0.70	15.8	-	-	-
2194	86**	3.6%	2.42††	1.11	34.4	-	20.6	65°
2194	86	3.6%	-	2.35	90.6	-	89.0	80°
2194	87	-	1.08	0.56	9.5	7.45	-	-
2194	88	-	-	0.59	10.8	-	12.5	75°
2194	89	9.1%	-	0.52	7.7	-	-	-
2192	259	-	-	1.32	43.9	-	50.8†	-
2192	261	-	-	1.27	41.6	-	53.5†	-
2192	309	-	-	1.11	34.4	-	41.7†	-
2192	346	-	-	1.25	40.7	-	32.8†	-
2192	366	-	-	1.15	36.2	-	25.6†	-

* Derived from the relation $\sigma_c = 45.3\ (CI\#) - 15.9$
** Sample sheared
† Average angle of break to core axis = 83°
†† Tested parallel to bedding


DIRECT SHEAR TEST
SAMPLE # 58
SLICKENSIDED SILTSTONE JOINT
τ (N)
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
σc (N)
26°

Sandstone

Average Sample Description

Medium grey, medium grained salt and pepper textured sandstone. Very calcareous, any jointing is generally infilled with calcite. Often contains fragmented coaly lamellae, possibly rootlets. Generally massive but may contain carbonaceous banding. Planar jointing systems seldom show signs of shearing but are often infilled. Generally cohesive and intact but easily break down when subjected to the elements.

LABORATORY TEST RESULTS: SANDSTONE

Corehole Number	Sample Number	As Received Moisture Content	Brazilian Disc (MPa)	Cone Indenter (CI#)	Cone Indenter (MPa)**	Uniaxial Compressive Strength: Solid Platen (MPa)	Uniaxial Compressive Strength: Brush Platen (MPa)	Uniaxial Compressive Strength: Angle of Break To Core Axis
2193	59	4.5%	0.07*	0.77	19.0	-	-	-
2193	61	2.2%	1.40*	0.77	19.0	-	-	-
2193	62	-	1.40*	0.89	24.4	-	-	-
2193	63	-	0.01*	0.56	9.5	14.7	-	-
2193	66	-	2.07	1.63	57.9	-	32.7	85°
2193	68	7.7%	-	0.63	12.6	-	17.3	75°
2193	72	-	-	0.89	24.4	51.6	-	80°
2194	73	6.7%	4.73	1.76	63.8	52.6	-	-
2194	75	9.6%	0.01*	0.56	9.5	-	-	-
2194	81	7.2%	1.35	0.69	15.4	-	-	-
2194	84	-	2.79	0.95	27.1	-	-	-
2194	88	-	-	1.06	32.1	12.5	-	70°

* Tests conducted parallel to bedding

** Derived from the relation $\sigma_c = 45.3\ (CI\#) - 15.9$

LABORATORY TEST RESULTS: SANDSTONE

Corehole Number	Sample Number	Cone Indenter		Uniaxial Compressive Strength	
		(CI#)	(MPa)*	Solid Platen (MPa)†	Brush Platen (MPa)††
2192	256	2.44	94.6	7.0**	-
2192	265	2.05	77.0	-	77.0
2192	266	1.81	65.6	81.7	-
2192	269	1.15	36.2	44.7	-
2192	271	1.25	40.7	32.6	-
2192	272	1.59	56.1	15.6**	-
2192	273	1.41	48.0	78.8	-
2192	274	1.63	57.9	57.3	-
2192	297	1.35	45.3	14.2**	-
2192	341	1.72	62.0	72.3	-
2192	350	1.72	41.6	33.9	-

* Derived from the relation σ_c = 45.3 (CI#) - 15.9
** Failure occurred along a joint plane
† Average angle of break to core axis = 70°
†† Average angle of break to core axis = 83°

Coal

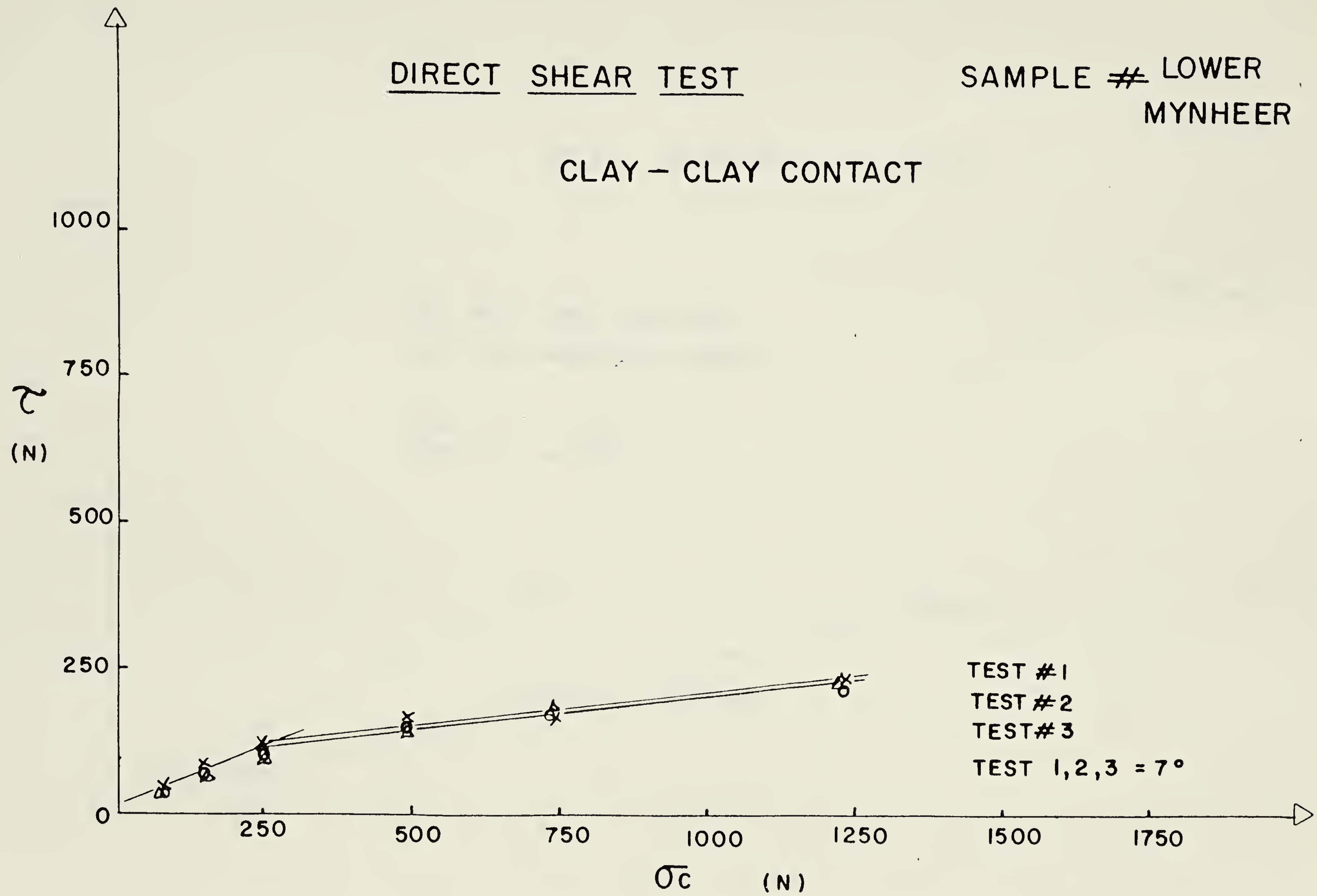
Average Sample Description

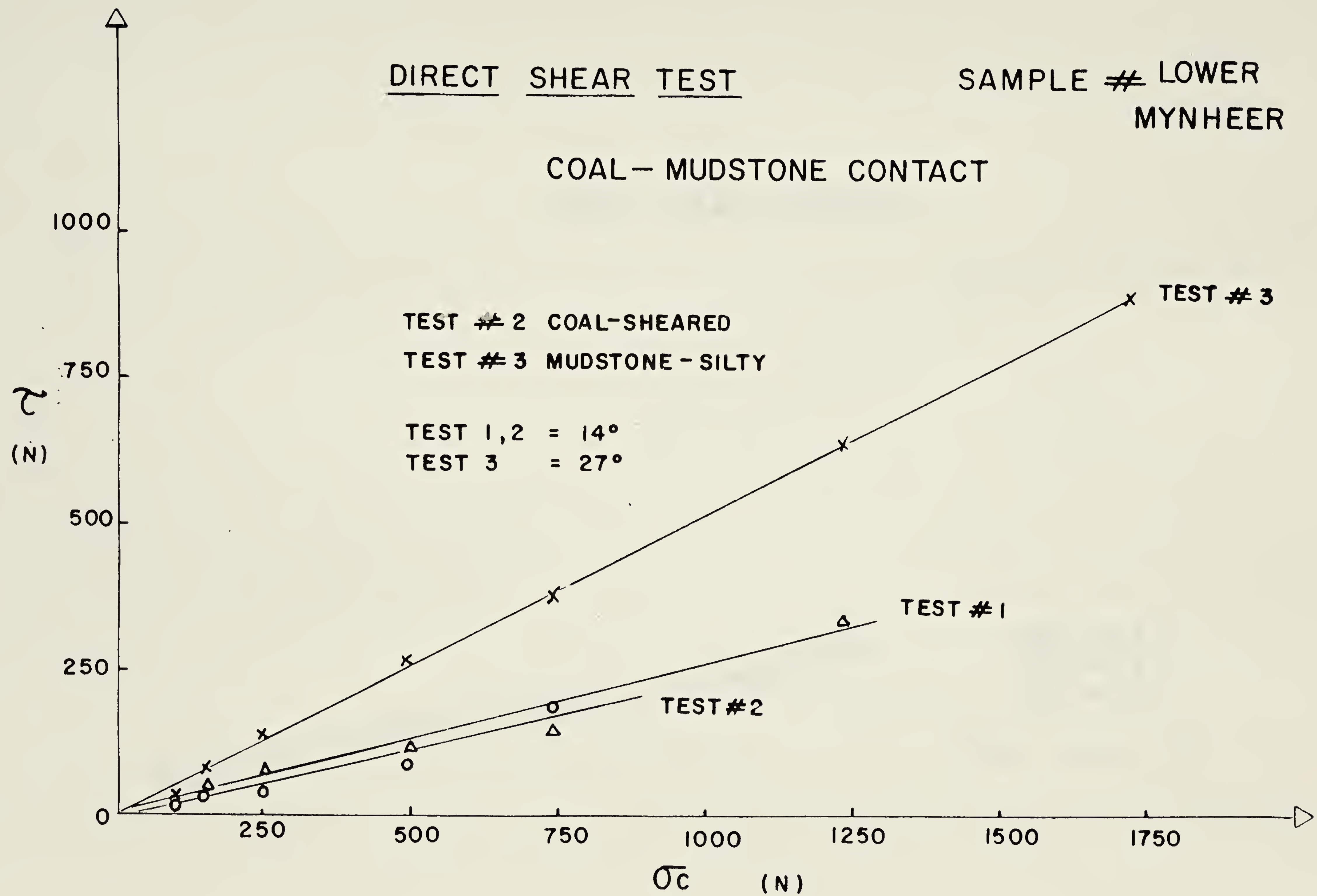
Coal samples were derived from Lower Mynheer seam, resulting in generally dull black dirty coals with high clay contents. Seatearth samples were common, consisting of dark grey to black gritty, carbonaceous clays. One to two foot thick clean coal in Lower Mynheer was generally sheared, exhibiting highly polished and slickensided shear planes. Clean coal fairly intact with possible conchoidal fractures. Testing on coal generally limited to contacts between clays and/or mudstones.

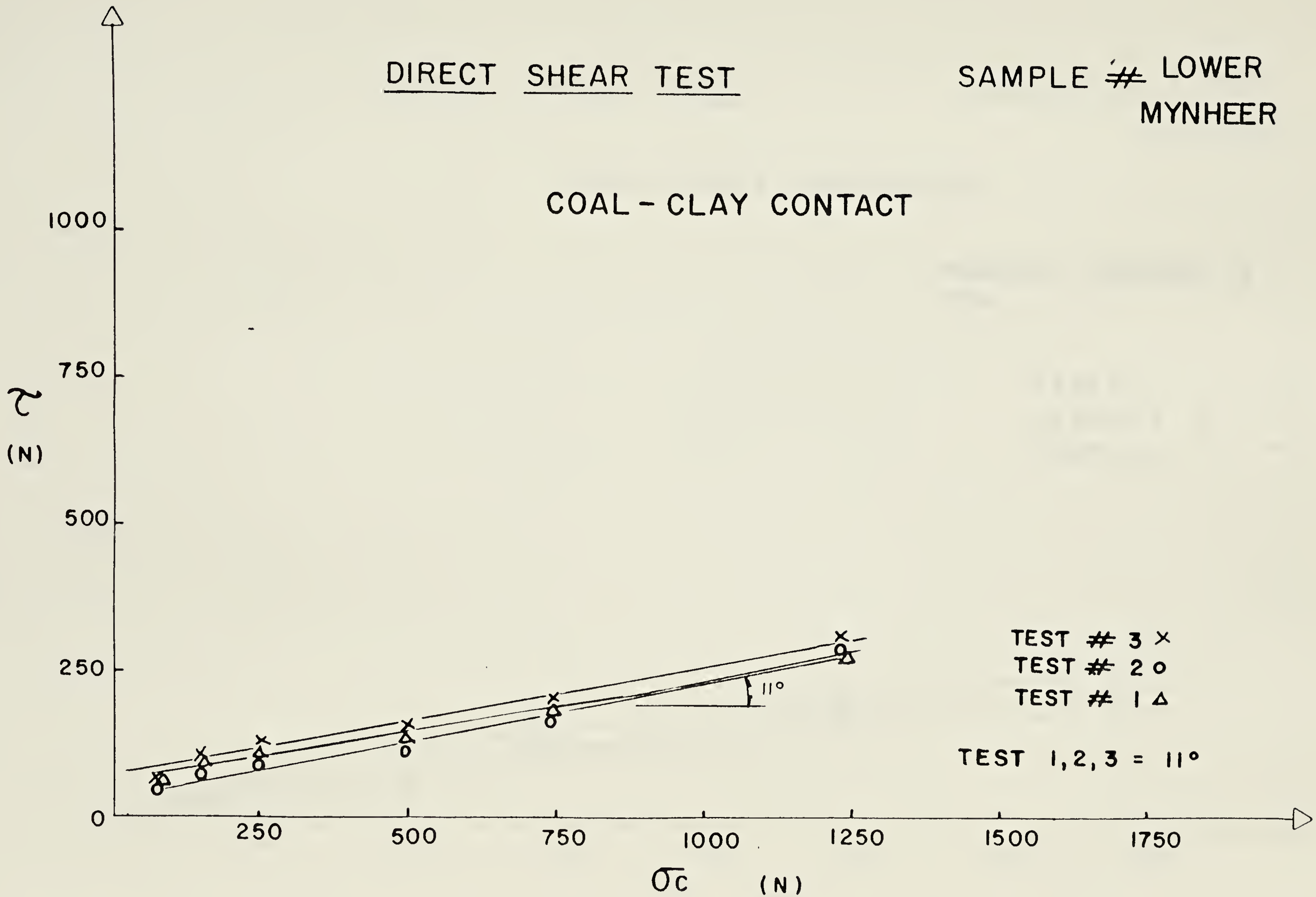
DIRECT SHEAR TEST RESULTS

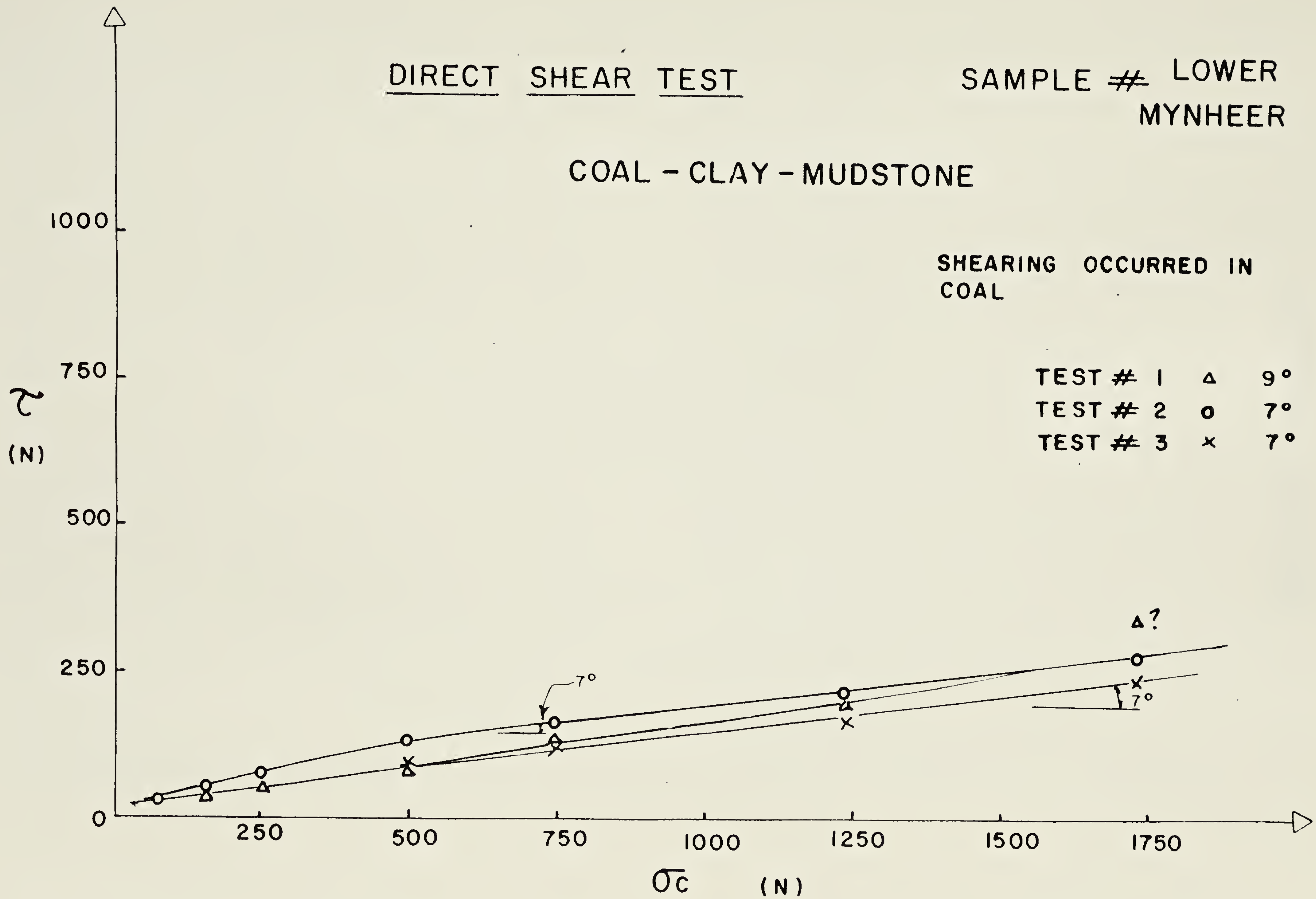
Lower Mynheer Grab Samples

Contact	Sample Number	Direct Shear ϕ'_p	ϕ'_r	C' (kPa)
	1	-	7°	0
Clay-Clay	2	-	7°	0
	3	-	7°	0
	1	-	14°	0
Coal-Mudstone	2	-	14°	0
	3	27°	-	0
	1	-	11°	13.7
Coal-Clay	2	-	11°	13.7
	3	-	11°	13.7
	1	-	9°	0
Coal-Clay-Mudstone	2	-	7°	0
	3	-	7°	0


DIRECT SHEAR TEST
SAMPLE # LOWER MYNHEER
CLAY – CLAY CONTACT
τ (N)
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
σc (N)
TEST #1
TEST #2
TEST #3
TEST 1,2,3 = 7°


DIRECT SHEAR TEST
SAMPLE # LOWER MYNHEER
COAL – MUDSTONE CONTACT
TEST # 2 COAL-SHEARED
TEST # 3 MUDSTONE - SILTY
TEST 1,2 = 14°
TEST 3 = 27°
TEST # 3
TEST # 1
TEST # 2
τ (N)
0
250
500
750
1000
1250
1500
1750
σc (N)


DIRECT SHEAR TEST
SAMPLE # LOWER MYNHEER
COAL - CLAY CONTACT
τ (N)
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
σc (N)
11°
TEST # 3 ×
TEST # 2 o
TEST # 1 Δ
TEST 1,2,3 = 11°


DIRECT SHEAR TEST
SAMPLE # LOWER MYNHEER
COAL - CLAY - MUDSTONE
SHEARING OCCURRED IN COAL
TEST # 1 △ 9°
TEST # 2 o 7°
TEST # 3 × 7°
△?
7°
7°
τ (N)
0
250
500
750
1000
1250
1500
1750
σc (N)

Appendix C - Core Logs

Corehole Log

GEOTECHNICAL SERVICES

Hole No. CH 2191
Page 1 of 10

Project Coal Valley Pit 13 Location 39037 N 78129 E Elev. 4664 Dip 1° Bearing Date June 20/79

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					50		0 - 44 - Clay Till	
							44 - 45 S.S.	
							Start core at 55'	
					55			
1	8	6	75			SANDSTONE	Grey, fine gr., very soft, clayey	Fill ?
						SAND		
						MUDSTONE	Dk grey, aphanitic, broken, coaly lenses	
					60	CLAY	Dk brown to grey, bentonitic, coaly inclusions	
2	8	5.9	74			COAL	Broken fragments 1-2" θ	
					65	BENTONITE	Lt. grey, soft, moist	
				#1 65-67		COAL		
					70	BENTONITE	Lt. grey, soft, moist	
3	8	7	88					
				#2 74.6 - 75.7	75			
						MUDSTONE	Dk. grey, broken	
						SANDSTONE	Grey, very soft, bentonitic, fine grained	
4	8	8	100		80			
					85			

Weathering | Strength or RQD | Defect Spacing mm

Drilling Rig Failing 1250(6) Hole Diameter 5½"
Drill Method air-water/mud Bit used Carbine & diamond
Driller Bendfeld R. Logged by KWH
Down hole surveys

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley Location N 39037 E 78129 Elev. 4664 Dip ____ Bearing ____

Hole No. CH 2191 Page 2 of 10 Date June 20/79

Run No.	Length of run	Length recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
				#3	85	SANDSTONE	Grey, fine grained, very soft, bentonitic	
				86-87		SILTSTONE		
5	6	6	100					
				#4				
				87-	90			
				93				
6	8	9	113			BENTONITE	Lt. grey, moist, soft	
						CLAY		
					95			
						SILSTONE	Lt. grey, bentonitic, very soft	
					100			
7	8	7.5	94			MUDSTONE	Dk. grey, fractured, broken	
				#5				
				103-		SILTSTONE	Lt. grey, bentonitic, very soft	
				103.8	105			
8	8	7.8	98		110			Joint 20° TCA, striated @ 80° TMA
								crushed zone
						SANDSTONE	Grey to red brown, fine to med.	
							grained, iron stained joints,	
					115		hard, salt & pepper texture	Joint, 40° TCA, clean, iron stained
				#6				Joint, 70° TCA, smooth, clean
				116.2-				
9	8	7.2	90	116.9			Faint bedding 70°TCA, thinly lam.	Joint 40° TCA, clean, iron stained
					120			

Drilling Rig ____ Hole Diameter ____ Down hole surveys
Drill Method ____ Bit used ____

Water: ▽ 11, APRIL 79 WATER LEVEL; ▶ WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley Pit 13 Location N 39037 E 78129 Elev. 4664 Dip ______ Bearing ______ Date June 20/79

Hole No. CH 2191 Page 3 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
				#7	120			SANDSTONE	Lt. grey, salt & pepper, fine to med.				
				121.3					grained, hard, some iron stained				
				-122.7					joints 40-55°				
													Jt 50° TCA, Fe stain, clean, smooth
					125								
10	7	1.6	23										
					130								
11	8	7.9	99										Switch from carbide to diamond bit at 132'
					135								
				#8	140								
12	8	7.9	99	139-140									
				#9	145								
				146-147									
13	4	3.8	95										
					150								
14	8	7.4	93										
					155								

Drilling Rig ______ Hole Diameter ______ Down hole surveys

Drill Method ______ Bit used ______

Water: ▼ 11, APRIL 79 WATER LEVEL; ▶ WATER INFLOW

Strength (indirect tensile strength)

Weathering

Corehole Log

GEOTECHNICAL SERVICES

Hole No. CH 2191 — Page 4 of 10

Project: Coal Valley Pit 13 — Location: N 39037 E 78129 — Elev. 4664 — Dip — Bearing — Date: June 22/79

Run No.	Length of run	Core recovered	% recovery	Samples Tests	Depth ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					155	SANDSTONE	Grey, salt & pepper, fine to med. grained, occasional iron stained joint, faintly laminated 80° TCA	
								- Joint 65° TCA, planar, smooth, striated TMA
					160			- Joint 30° TCA, Fe stained, planar, smooth
15	8	7.4	93					
				#10 162.4-163.2				
					165			
								- Joint 75° TCA, planar smooth
16	8	8.9	111	#11 168-169.1				
					170			- Joint 10° TCA, rough, irregular, Fe stained
					175			
17	8	6	75			MUDSTONE	Dk. grey, aphanitic	176-177 fragmented, broken, faces are striated & slick
				#12 180.7-182	180			
18	8	7.2	90		185		Grades to siltstone	
						SILTSTONE	Lt. grey, v. fine grained	Jointed 40° TCA, joints are planar striated // TMA, slick
				#13 188.9-189.8				
					190			

Drilling Rig ______ Hole Diameter ______ Down hole surveys / Type

Drill Method ______ Bit used ______

Other ______ Logged by ______

* point load test

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

Geotechnical Services

Corehole Log

Project Coal Valley Pit 13 — Location N 39037 E 78129 — Elev. 4664 — Dip ______ — Bearing ______

Hole No. CH 2191 — Page 5 of 10 — Date June 22/79

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					190	SILTSTONE	Grey, v. fine grained	Jointed as before to 192'
								some thin calcite stringers
19	8	7.9	99				- some iron stained joints	
							- broken up crushed zones ~ 1' apart	
					195		192 - 204	
20	8	7.5	94		200			
							- faint laminations ~ 85° TCA	
					205		- definite laminations 70-85° TCA	
							from 206 - 210	
21	8	7.9	99					
					210			
							grades to mudstone	
						MUDSTONE	dark grey, aphanitic	joint, 35° TCA, carved irregular, slick
					215		carbonaceous	joint 50° TCA, curved, irregular slick ⊥ TMA
22	7	6.7	96					
							carb. at 218-219, thinly lam. 65° TCA	joint 65° TCA, clay filled, rough
					220			jointed 65°, planar, smooth, striate ⊥ TMA
							calcite filled jts. 50° TCA	
								joint 40° TCA, planar, slick, striated // TM
23	6	7.2	120					
					225			

Bit used ______ — Surveys — WATER LEVEL — WATER INFLOW

Geotechnical Services

Corehole Log

Project: Coal Valley Pit 13 Location: N 39037 E 78129 Elev.: 4664 Dip: Bearing:

Hole No.: CH 2191 Page 6 of 10 Date: June 22/79

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					225	MUDSTONE	as before	- 225.5 - 229 shear zone
								very soft, jointed 60° TCA
								slick plated structure, broken easily
24	8	7.1	89		230		grades to Siltstone	
								joints 40° TCA, planar, clean
				#18		SILTSTONE	grey, very fine grained, massive	
				233.8-				
				236.1				
					235			
25	7	7.1	101					jt. 55° TCA, planar, calcite veneer
					240			
				#19			thinly laminated 65° TCA	
				242.6-				
				244.1			Grades to mudstone	
26	8	7.6	95		245	MUDSTONE	Grey, aphanitic, thinly laminated	
							@ 70° TCA	
							246-247 contorted, sheared, fragmented	contact with sheared mudstone at 55° TCA
				#20			fragment faces are slick	
				247 -				
				248.5	250			
							Very soft, bentonitic, (251-252)	
							contorted, sheared 252-254.5	
27	8	8.9	111					
				#21	255			
				257.1-				
				258			Grades to S.S.	
						SANDSTONE	Grey, fine grained, thin coaly laminations	
28	8	5.5	69		260		at 70-80° TCA	

Method ______ Hole Diameter ______ Bit used ______ Downhole surveys

WATER LEVEL
WATER INFLOW

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley Pit 13 Location N 39037 E 78129 Elev. 4664 Dip ____ Bearing ____

Hole No. CH 2191 Page 7 of 10 Date June 23/79

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
				#22	260	MUDSTONE	Dark grey, aphanitic	
				260-			261-262.5 thinly laminated	@ 262.5 - 264.8 sheared, contorted
				261.1			@ 30° TCA	fracture faces slick
							contact at 60° TCA	
					265	COAL		
29	6	1.5	25					
					270	MUDSTONE	Grey, aph. some silty, sandy areas	
							271-273 jointed 45-55°TCA	
							fracture faces slick	
30	6	10	167					
							276.2 - thin coal seam 45° TCA	
							276.2 - 280 - soft, fractured	
							slick	
31	8	7.4	93	#23	280	SILTSTONE	Lt. grey, v. fine grained, sandy	
				282.7-				
				284.5				
							grades to S.S.	
						SANDSTONE	Lt. grey, fine grained, silty	
							faintly laminated 40-50° TCA	
							from 286-301	
							occ. joints 50-70°, clean, smooth	
32	8	7.9	99				breaks along bedding	
					290			jt. 50° TCA, planar, calcite filled
					295			

Drilling Rig ____ Hole Diameter ____ Down hole surveys

Drill Method ____ Bit used ____

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW, VL VERY LOW, L LOW, M MEDIUM

Weathering: FR FRESH, SW SLIGHTLY WEATHERED, MW MODERATELY WEATHERED, HW HIGHLY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Project Coal Valley Pit 13 Location N 39037 E 78129 Elev. 4664 Dip Bearing

Hole No CH 2191 Date June 23/79 Page 8 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					295			SANDSTONE	Lt. grey, fine grained, silty				
33	8	6	75										
				#25 299.3-301	300								
								MUDSTONE	Dk. grey, as before				
									contact with S.S. at 68° TCA				
									grades to S.S.				303.5-305 thin coaly lam. @ 65°
34	8	10	125		305			SANDSTONE	As above				
													309 - 311.5 coaly laminations 70-80°
					310								
35	8	8	100										
				#27 316.6-317.4	315								315.5-317 coaly lam. 70-80°
					320								jt. 70°TCA, clean, planar, smooth
36	8	6	75										
													jts. 45° TCA, planar, calcite filled
				#28 326.8-327.8	325								
37	8	10.3	129										
					330			COAL	Contact @ 329.6' @ 70° TCA				

Drilling Rig Hole Diameter Down hole surveys

Drill Method Bit used Type

Logged by * point load test

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD

Project Coal Valley, Pit 13

Corehole Log

Location N 39037 E 78129

GEOTECHNICAL SERVICES

Elev. 4664 Dip Bearing

Hole No CH 2191

Date June 24/79 Page 9 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					330	COAL	Black, hard, fractured, jointed 50° - 60° TCA	
				#29 332.3-333.5				
					335			
38	8	7.8	98					
					340			
39	7	7.8	111	#30 345.8-346.7			Contorted & sheared, fracture or joint faces slick, 10-20° TCA	
					350	MUDSTONE	Carb., dark grey brown	
40	8	8.2	103					
				#31 355.1-356.2				
41	8	8.2	103	#32 359.5-361	360	MUDSTONE	Carb., as above	
						MUDSTONE	Carb., coaly	
					365			

Drilling Rig ______ Hole Diameter ______

Drill Method ______ Bit used ______

Down hole surveys

Type

* point load test

Water: ▼ WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Hole No CH 2191

Project Coal Valley Pit 13 | Location N 39037 E 78129 | Elev. 4664 | Dip | Bearing | Date June 24/79 | Page 10 of 10

Run No.	Length of run	footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					365			COAL					
42	8	7.9	99					MUDSTONE	Carb. dk. grey brown grades to siltstone				
					370			SILTSTONE	Grey, very fine grained thinly bedded 70-80° TCA				
43	5	0	0										
Total			93										
					380				TD 380'				

Drilling Rig | Hole Diameter | Down hole surveys
Drill Method | Bit used | Type
Driller | Logged by

* point load test

Water: ▼ 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD
Project COAL VALLEY Pit 13

Corehole Log

Location N 39660 E 78190

GEOTECHNICAL SERVICES

Elev. 4784 Dip Bearing

Hole No CH 2192

Date June 25/79 Page 1 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					50			
					55		55 feet - start core	
1	8	4.5	55			MUDSTONE	Dk. grey, aphanitic, badly broken	
								Calcite
								Striations 20° TCA
					60			
2	8	5.6	70			CLAY	Bentonitic, lt. brown	
						MUDSTONE	Dk. grey aphanitic, badly broken	
					65			
				Samp.37				
				66.1-67.6				
						CLAY	Lt. grey to brown, bentonitic	
					70			
3	8	6.2	78			CLAY	Grey bentonitic	
						MUDSTONE	Dk. grey aphanitic badly broken	
						CLAY	Grey bentonitic	
					75			
						MUDSTONE	Dk. grey aphanitic broken	
4	8	5.4	68			MUDSTONE	Dk. grey aphanitic broken	
					80	CLAY	Lt. grey bentonitic	
						MUDSTONE	Dk. grey aphanitic broken	
						CLAY	Grey bentonitic	

Drilling Rig Failing 1250(6) Hole Diameter 5½
Drill Method Air-water Bit used carbide & diamond
Logged by R. Bendfeld Checked by CPA

Down hole Surveys Type

* point load test

Water: ▼ 11/APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD | Corehole Log | GEOTECHNICAL SERVICES | Hole No CH 2192

Project · Coal Valley Pit 13 | Location N 39660 E 78190 | Elev. 4784 | Dip | Bearing | Date June 25/79 | Page 2 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					85								
5	6	5.9	98					MUDSTONE	Bentonitic lt. grey				
					90								
				Samp.38				Interbedded	broken mudstones				
				90.3-91.3				CLAY					Laminations at 45° TCA
6	8	9.8	122					MUDSTONE	Lt. grey bentonitic				
					95								
				Samp.39									
				97.0-98.0									
					100			MUDSTONE	Dk. grey broken				
7	8	9.7	121					MUDSTONE	Lt. grey bentonitic				
					105								
								MUDSTONE	Dk. grey aphanitic broken				
								CLAY MUDST	Lt. grey bentonitic				interbedded broken mudstones
8	8	7.6	95					CLAY MUDST.	Lt. grey bentonitic broken				
					110								
								MUDSTONE	Dk. grey aphanitic broken				
								CLAY MUDST.	Interbedded Clays and Mudstones				
								CLAY	White bentonitic				
				Samp.40	115								
				115-117					Dk. grey				
9	8	7.5	94					CLAY	Green chloritic				
					120			COAL	Clayey, broken				

Drilling Rig ______ Hole Diameter ______ Down hole surveys

Drill Method ______ Bit used ______ Type

* point load test

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley, Pit 13 Location N 39600 E 78190 Elev. 4784 Dip ______ Bearing ______

Hole No. CH2192 Page 3 of 10 Date June 25, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					120	Clayey Coal		
						Clay	Green chloritic	
						Mudstone	Light grey aphanitic	
					125	Clay	Grey-Green	
10	8	5.5	69			Clayey Siltstone		
						Silty Clay	Grey	Carbonaceous Stringer 2" Thick at 60° TCA
					130	Siltstone	Grey Poorly consolidated	
11	8	7.1	90			Sandstone	Grey weathered, silty soft	
					135			
					140			
12	8	5.4	68					
						Sandstone	Grey Silty Soft Weathered	
						Siltstone	Grey Sandy Broken	
						Mudstone	Grey Poorly Consolidated Aphanitic	
						Clay	Light Grey Bentanitic	
					145	Mudstone	Broken Grey Aphanitic	
13	8	3.8	48					
						Mudstone	Dark Grey Aphanitic Badly Broken	
					150			Laminations at 50° TCA
						Sandstone	Medium Grey Calcareous Broken	Laminations at 25° TCA
					155			

Columns also printed: Graphic Log, Water, Weathering, Strength or RQD, Defect Spacing mm.

Drilling Rig ______ Hole Diameter ______ Down hole surveys

Drill Method ______ Bit used ______

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Hole No. CH2192
Page 4 of 10
Project Coal Valley Pit 13 Location N 39960 E78190 Elev. 4784 Dip ______ Bearing ______ Date June 26, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					155			
14	8	7.6	95			Sandstone	Medium Grey Clacareous	
								Laminations 20° TCA
					160			
				Sample41 163-164 ft				
					165			
15	8	7.5	94			Sandstone	Medium Grey	
						Siltstone	Medium Grey	
					170			
						Mudstone	Dark Grey Badly Broken	
16	8	8.4	105					
						Mudstone	Dark Grey Aphanitic	
					175			Joints 10° TCA irregular slicks
					180			
17	8	7.8	95			Siltstone	Dark Grey	
						Mudstone	Dark Grey Aphanitic	Random Jointing Slick
					185			
						Siltstone	Clayey Dark Grey	
						Mudstone	Dark Grey Silty	
				Sample42 1875-189				
18	8	7.6	95			Mudstone	Medium Grey Aphanitic	

Drilling Rig ______ Hole Diameter ______ Down hole surveys
Drill Method ______ Bit used ______

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength)

Weathering

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley, Pit 13 Location N39660 E78190 Elev. 4784 Dip ______ Bearing ______

Hole No. CH2192
Page 5 of 10
Date June 26, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					190			Mudstone	Medium Dark Grey Aphanitic Some Thin				
									Silty Layers				Jointing Random
					195								
19	8	8	100					Mudstone	Medium Dark Grey Aphanitic				
					200								
				Sample43									Frequent Random Jointed Irregular Slicks
				2031-205									
					205								
20	8	7.7	92					Mudstone	Medium Dark Grey Aphanitic				
					210			Mudstone	Medium Dark Grey Silty				
								Mudstone	Medium Dark Grey Aphanitic				
21	8	7.4	92					Mudstone	Dark Grey Aphanitic				
					215								
									Silty				
					220								
22	8	7.4	92					Mudstone	Medium Grey Aphanitic				
								Coal Clay	Carbonaceous Black				
					225								

Drilling Rig ______ Hole Diameter ______ Down hole surveys
Drill Method ______ Bit used ______

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley, Pit 13 Location N 39600 E78190 Elev. 4748 Dip Bearing

Hole No. CH2192 Page 6 of 10 Date June 26, 1979

Run No.	Run length	Core recovered	% recovery	Samples Tests	Depth in ft. or m	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, components (minor)	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					225			Coal	Clay, Black				Joints 30° TCA, Planar
				Sample44									
				227.0-228	5			Mudstone	Carbanaceous Aphanitic				
23	8	8.5	106		230			Coal	Black Clayey				Laminations 20° TCA
									Intermittent clay layers up to 1" thick				
				Sample45									
				2325-234									
					235			Coal	Black Dull				Joints at 45° TCA
									Interbedded Mudstones				
24	8	8	100					Coal	Black Dull				Joints at 30° TCA
								Clay Bentonite					
								Coal	Dull Black				
					240			Coal / Mudstone	Grey Medium Brown				
								Bentonite					
								Coal	Clayey Dull Black				
													Joints random orientated, planar
								Mudstone	Dark Grey - Medium Grey Carb.				
25	8	8	100		245			Interbedded	Coals and Carb. mudstones				
									Black - Dark Grey				Laminations at 60° TCA
								Coal	Black Dull				
								Mudstone	Bentonitic - Light Grey				
					250			Coal	Clayey Dull Black				Joints random, planar
				Sample46				Mudstone	Dark Grey, Carb. Some Bentonite				
				2515-253				Coal	Black Dull				
26	8	7.2	90					Siltstone	Medium Grey Calciteveins				
					255								Joints 45° TCA Planar Stick
								Mudstone	Medium Grey Aphanitic				
					260								

Drilling Rig Hole Diameter Down hole surveys

Drill Method Bit used

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Hole No. CH2192
Page 7 of 10

Proj. Coal Valley, Pit 13 Location N39660 E78190 Elev. 4784 Dip Bearing Date June 27, 1979

Run No.	Core run	Core recovered	% recovery	Samples Tests	Depth in ft. or m	Rock Type	color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					260			
27	8	8.1	101			Mudstone	Medium Grey Aphanitic	
					265	Siltstone	Medium Grey	
								Joints 50° TCA, Planar Slick
				Sample47			Clayey	
				2677-264				
28	8	7.7	96		270	Sandatone	Calnaceous - Calciteveins	Joints 50° TCA Planar
							Medium Grey	
					275	Mudstone	Medium Grey Aphanitic	Laminations 40° TCA
29	8	7.3	91			Mudstone	Dark Grey Carb. Aphanitic	
								Joints at 80° TCA Planar Slick
					280	Mudstone	Dark Grey Chloritic Aphanitic	
						Siltstone	Clayey Medium Grey	
								Random Jointa Planar
					285			
30	8	7.8	95	Sample48		Mudstone	Medium Grey Chloritic Aphanitic	
				285-287.7			Broken	
						Clay	Carb. Dark Grey	
						Mudstone	Medium Grey Aphanitic	
								Jointa 85° TCA Planar Slick
					290			
31	8	8.5	106			Sandstone	Medium Grey Calciteveina	
					295			

Drilling Rig Hole Diameter Down hole surveys
Drill Method Bit used

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTR. HELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley, Pit 13 Location N39660 E78190 Elev. 4784 Dip ____ Bearing ____

Hole No. CH2192 Page 8 of 10 Date June 17, 1979

Run No	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description (color, grain size, bedding, structure, minor components)	Rock Mass Defects (type, inclination, planarity, roughness, coating, thickness)
					295	Sandstone	Medium Grey, Calcite Veins	
								Random Jointing Planar
					300			
32	8	7.2	90					
						Mudstone	Medium Grey Silty Broken	
						Mudstone	Dark Grey Carb. Aphanitic	Bedding 85° TCA
					305			
						Siltstone	Medium Grey Clayey	Jointing 45° TCA Planar
33	8	7.9	99		310	Siltstone	Medium Grey Component	
							Calcite Veins	
				Sample49 3135-3145		Mudstone	Medium Grey Aphanitic	Bedding 70° TCA
					315	Siltstone	Medium Grey	Calcite Vein 3/8" Thick 60° TCA
						Mudstone	Medium Grey Aphanitic	
LC	317 - 335	18'						
					320			
							L O S T C O R E	
					325			
					330			

Drilling Rig ____ Drill Method ____ Hole Diameter ____ Bit used ____ Down hole surveys

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

Corehole Log

GEOTECHNICAL SERVICES

Project Coal Valley, Pit 13   Location N 39660 E78190   Elev. 4784   Dip ______   Bearing ______

Hole No. CH2192   Page 9 of 10   Date June 28, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					330			
36	6	5.6	93		335	Mudstone	Medium Grey Aphanitic	Jointing 50° TCA Planar
						Siltstone	Medium Grey	
						Mudstone	Layer 3" thick	Bedding 60° TCA
						Siltstone	Medium Grey	
						Sandstone	Medium Light Grey, Medium Grained	
37	8	8.8	110		340			
						Mudstone	Medium Grey - Green Chloritic	Bedding 50° TCA
							Silty	Jointing ⊥ to bedding, Planar
				Sample50	345	Siltstone	Red Grey Calcite Veins	
				346-347.5				Jointing ⊥ TCA Planar
38	8	5.0	63		350	Sandstone	Red Grey Medium Grained	Bedding 80° TCA
							Calcite Veins	
						Mudstone	Medium Grey Aphanitic	Jointing 15° TCA Striations
					355			
						Mudstone	Medium - Dark Grey Aphanitic	
39	7	7.7	110		360	Siltstone	Medium Grey	Bedding 60° TCA
						Mudstone	Medium Grey Aphanitic	Bedding 60° TCA
40	9	8.1	90		365			

Drilling Rig ______ Hole Diameter ______ Down hole surveys

Drill Method ______ Bit used ______

Water: ▼ 11, APRIL 79 WATER LEVEL; ▶ WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW, VL VERY LOW, L LOW, M MEDIUM

Weathering: FR FRESH, SW SLIGHTLY WEATHERED, MW MODERATELY WEATHERED, HW HIGHLY WEATHERED

GEOTECHNICAL SERVICES

Corehole Log

Project Coal Valley, Pit 13 — Location N 39660 E78910 — Elev. 4784 — Dip ____ — Bearing ____

Hole No. CH2192 — Page 10 of 10 — Date June 28, 1979

Run No	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					365	Siltstone	Medium dark grey, clayey	
								Bedding 65^{0} TCA
				51				Jointing TCA irregular
				368-368.8				
					370	Siltstone	Medium grey, sandy	
41	8	8.0	100			Siltstone	Dark grey	
					375	Mudstone	Green chloritic, silty	
								Jointing planar ⊥ TCA possibly bedding planes
						Siltstone	Green - calcite veins chloritic	
					380			
42	8	7.8	98			Sandstone	Medium grey, very fine grained	
						Mudstone	Medium grey, silty, broken	
					385			
Total			88			Siltstone	Medium grey, clayey	Random jointing planar
							Foot of Hole	
					390			
					395			
					400			

Drilling Rig ____ Hole Diameter ____ Down hole surveys

Drill Method ____ Bit used ____

Water: ▼ 11, APRIL 79 WATER LEVEL; ➤ WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

Corehole Log

GEOTECHNICAL SERVICES

Hole No. CH2193
Page 1 of 10
Date July 4, 1979

Project Coal Valley, Pit 13 Location N 39821 E78218 Elev. 4771 Dip ______ Bearing ______

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					30								
									Broken Mudstone				
					35								
1	8	6.4	80					Clay Mudst.	Light grey - white bentonitic, broken				
								Clay	Brown-chloritic				
					40								
								Mudstone	Clayey light grey - light brown, broken				Bedding 85° TCA
					45								
2	8	5.6	70					Mudstone	Light grey bentonitic broken				
								Siltstone	Clayey, light grey calc.veins broken				Jointing 11 TCA
					50								
3	8	8	100					Mudstone	Light grey				
					55								
								Siltstone	Medium grey badly broken				Bedding TCA
								Mudstone	chloritic, medium grey badly broken				
				54 59.5-61	60								
								Siltstone	Medium grey broken				
4	6	4.8	80					Siltstone	Medium grey broken chloritic				
					65								

Drilling Rig Failing 1250(6) Hole Diameter 5½
Drill Method air-water Bit used Diamond
D. Broen CPA
Down hole surveys

Water
11, APRIL 79 WATER LEVEL
WATER INFLOW

Strength (indirect tensile strength)
EL EXTREMELY LOW
VL VERY LOW
L LOW
M MEDIUM

Weathering
FR FRESH
SW SLIGHTLY WEATHERED
MW MODERATELY WEATHERED
HW HIGHLY WEATHERED

Geotechnical Services

Corehole Log

Project Coal Valley, Pit 13 Location N 39827 E78218 Elev. 4771 Dip ____ Bearing ____

Hole No. CH2193 Page 2 of 10 Date July 4, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					65			Sandstone	Calcite veins - light grey				bedding at 75° TCA
5	6	5.5	91										
					70			Siltstone	Light brown				Bedding at 75° TCA
6	8	8	100										
					75			Siltstone	Light grey, calcite veins				
								Mudstone	Light grey, calcite veins				Bedding at 75° TCA
					80								
				55									
7	8	7.4	93	81-82				Mudstone	Light grey				Bedding at 65° TCA
					85			Coal	Dark grey, black dull				
								Siltstone	lt.grey, frequent calc.veins coal incls.				
								Mudstone	Light grey, aphanitic				Bedding at 45° TCA
									broken				
8	8	5.8	7.3		90			Mudstone	Light grey - chloritic				Bedding at 64° TCA
				56									
				935-94.5	95			Mudstone	Brown broken				
9	8	7.8	95					Mudstone					
					100			Coal					Bedding at 80° TCA

Hole Diameter ____ Drill Method ____ Bit used ____ Down hole surveys

11 APRIL 79 WATER LEVEL
WATER INFLOW

Strength (indirect tensile strength)

Geotechnical Services

Corehole Log

Hole No. CH2193
Page 3 of 10

Project Coal Valley, Pit 13 Location N 39827 E78218 Elev. 4771 Dip ______ Bearing ______ Date July 5, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					100								
								Mudstone	Light grey-brown aphanitic				Bedding at 65° TCA
								Siltstone	Light grey - calcite bands				
					105			Mudstone	Medium grey - banded				Bedding at 65° TCA
10	8	5	63					Mudstone	highly sheared - chloritic med. grey				Shear zone
									light grey aphanitic				
								Siltstone	Light grey				
					110			Mudstone	Light grey - silty				Bedding at 60° TCA
								Mudstone	Sheared-chloritic				
								Siltstone	badly broken light grey				
									Lost core				
11	8	6.5	81		115			Siltstone	Light grey				
								Mudstone	sheared chloritic				
									Medium grey - brown				
					120								
12	8	6.5	81					Siltstone	Light grey				
								Mudstone	Medium grey chloritic				frequent jointing random
					125				badly broken				slick
13	8	6.9	86		130			Mudstone	broken medium grey aphanitic				
								Siltstone	Light grey				Bedding at 55° TCA
								Mudstone	Clay band - medium grey				
								Sandstone	Light - medium grey, calcite infillings				
					135								Bedding at 60° TCA

Hole Diameter ______ Method ______ Bit used ______ Downhole surveys

WATER LEVEL
WATER INFLOW

Geotechnical Services

Corehole Log

Hole No. CH2193
Page 4 of 10

Project Coal Valley, Pit 13 Location N39827 E78218 Elev. 4771 Dip ____ Bearing ____ Date July 6, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
				58	135								Bedding at 60° TCA
				135.7-137									
14	8	7.5	94					Siltstone	Light grey				Random joints slick
								Sandstone	Light grey				
					140								
								Siltstone	Light grey				
								Coal & Mdst.	Dark grey - dull black carb. muds &Coal				Jointing at 60° TCA
					145			Siltstone	Medium grey - calcite veins				Bedding at 75° TCA
15	8	6.2	77					Mudstone	Medium grey - badly broken				
				58				Siltstone	Light medium grey				
				147.5-148.6									
					150			Mudstone	Medium grey aphanitic				Random joints
16	8	9.1	114					Siltstone	Light grey				Jointing planar at 45° TCA
					155			Sandstone	Light grey				Bedding at 70° TCA
				59									
				157-158.1				Sandstone	Medium light grey				
					160			Siltstone	Medium grey				
								Sandstone	Medium grey				
17	8	7.6	95										
								Sandstone	Medium grey				
					165								
													Bedding at 60° TCA
								Mudstone &	Dark grey carb., badly broken & Sheared				
								Coal					Straitions on shear faces
				60									
				168.7-169.3	170								

Bit used ____ Drill hole surveys

WATER LEVEL
WATER INFLOW

Geotechnical Services

Corehole Log

Project: Coal Valley, Pit 13 | Location: N 39827 E78218 | Elev. 4771 | Dip | Bearing | Hole No. CH2193 | Page 5 of 10 | Date July 6, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
18	8	3.5	44		170			Mudstone	Medium grey, chloritic sheared				
								Siltstone	Medium grey, calcite veins				Bedding at 75° TCA
					175								
								Sandstone	Light - medium grey				
19	8	10	125										Bedding at 50° TCA
					180								Jointing to bedding
20	8	8.0	100	61 184-185	185			Mudstone	Medium grey - aphanitic				
													Bedding at 70° TCA
													Jointing 11 TCA
								Siltstone	Medium grey				Bedding at 60° TCA
					190			Mudstone	Medium grey aphanitic, sheared				Deposits sheared, slick on shear face
								Mudstone	Medium grey - green				Joints TCA Irregular
					195			Mudstone	Clayey - Medium-dark grey				Straitions on joint faces
22	9	8.5						Mudstone	Medium grey aphanitic				
													Bedding at 45° TCA
					200								
22	9	8.5	94										
								Siltstone	Medium grey				Bedding at 40° TCA
					205								

Method ___ Hole Diameter ___ Bit used ___ Down hole surveys

WATER LEVEL
WATER INFLOW

Geotechnical Services

Corehole Log

Project Coal Valley, Pit 13 Location N39827 E78218 Elev. 4771 Dip ______ Bearing ______

Hole No. CH2193 Page 6 of 10 Date July 6, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					205								Bedding at 40° TCA
				205-206.1				Siltstone	Medium grey				
								Sandstone	Medium grey				
								Mudstone	Medium grey aphanitic				
					210								Bedding at 35° TCA
23	8	7.4	92										
								Siltstone	Medium light grey				
													Bedding at 40° TCA
					215								Random joints, planar
24	8	7.4	93					Sandstone	Medium grained calcite infilling				
					220			Siltstone	Sandy - medium grey				Bedding at 45° TCA
													Jointing to bedding
								Sandstone	Medium coarse, medium grey calcite				
				63									
				2245-2255	225								
25	8	8.7	109					Sandstone	Coarse Grained, Calcite veins				Bedding at 60° TCA
									Medium grey				
								Mudstone	Medium grey				Jointing 11 TCA
					230								
								Siltstone	Sandy, medium grey				Bedding at 40° TCA
								Mudstone	Medium grey - aphanitic broken				
26	8	8.0	100		235			Siltstone	Medium grey				
								Mudstone	Medium grey - aphanitic				Jointing 55° TCA
				64									
				2385-2393				Mudstone					

Method ______ Bit used ______ Surveys

WATER LEVEL
WATER INFLOW

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Hole No CH2193

Project Coal Valley, Pit 13 Location N39827 E78218 Elev. 4771 Dip Bearing Date July 7, 1979 Page 7 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					240			Mudstone	Med.grey,carb.stringer @ 240'-2" thick				
													Bedding at 65° TCA
27	8	7.8	98						Competent				
					245								
								Mudstone	Carbanaceous dark grey - broken,				
					250								
				65									
				2487-250				Siltstone	Medium grey				
								Sandstone	Fine grained - competent				Bedding at 50° TCA
				66									
				254-254.9	255			Sandstone	Medium grey				
29	8	6.7	84					Sandstone	Medium grey - fine grained				
					260								Bedding at 70° TCA
									Medium grained				
								Siltstone	Medium grey				
					265			Mudstone	Medium dark grey aphanitic				Random irregular jointa
30	8	8.8	110					Siltstone	Medium grey, competent				
				67									
				2695-2698				~~Mudstone~~	~~Medium grey,brown~~				
					270			~~Mudstone~~	Medium grey				
								Siltstone	Medium grey				Bedding at 80° TCA
								Mudstone	Dark grey aphanitic				
31	8	7.6	95		270								

Drilling Rig ______ Hole Diameter ______ Down hole surveys Type

Drill Method ______ Bit used ______

Logged by

* point load test

Water: 11 APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL - EXTREMELY LOW; VL - VERY LOW; L - LOW; M - MEDIUM; H - HIGH; VH - VERY HIGH; EH - EXTREMELY HIGH

Weathering: FR - FRESH; SW - SLIGHTLY WEATHERED; MW - MODERATELY WEATHERED; HW - HIGHLY WEATHERED; EW - EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Hole No CH2193

Project Coal Valley, Pit 13 Location N 39827 E78218 Elev. 4771 Dip Bearing Date July 7, 1979 Page 8 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					275			Mudstone	Dark grey, aphanitic				Planar joints
								Siltstone	Medium grey				Bedding at 85° TCA
								Mudstone	Dark grey, aphanitic				
								Siltstone	Sandy, medium grey				
				68					Calcite veins				Bedding at 75° TCA
				281-281.7									
32	8	8.0	100										
								Siltstone	Medium grey banding				Bedding at 85° TCA
					285			Sandstone	Medium grey, competent				Jointing random - planar
									Calcite infillings fine grained				
													Bedding indiatinghishable
					290								
33	8	7.0	89					Siltstone	Medium grey				
								Mudstone	Medium dark grey, aphanitic				
					295			Siltstone	Medium grey - dark grey				Jointing at 60° TCA Planar
34	8	8.2	102					Mudstone	Medium-dark grey, aphanitic				Jointing at 13° TCA
					300								Bedding at 45° TCA
								Siltstone	Medium-dark grey				
													Jointing random
													Bedding 45° TCA
					305			Mudstone	Medium-dark grey, aphanitic				
				69									
35	8	7.6	95	3047-306				Mudstone	Medium-dark grey, some shearing				
									aphanitic				
													Jointing at 15° TCA
					310			Siltstone	Medium-grey, broken				

Drilling Rig Hole Diameter Down hole surveys Type
Drill Method Bit used
Logged by

✱ point load test

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Project Coal Valley, Pit 13 Location N39827 E78218 Elev. .4771 Dip Bearing

Hole No CH2193 Date July 7, 1979 Page 9 of 10

Run No.	Length of run	footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Lithological Description: Rock Type	color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					310			Siltstone	Medium-grey, broken				
								Mudstone	Medium-dark grey, sheared				Shear Zone
36	8	8.4	105										
					315			Siltstone	Medium-grey, sandy				Bedding at 60^{o} TCA
													Jointing TCA
								Mudstone	Dark-grey, broken aphanitic				
					320			Siltstone	Medium-dary grey				
								Mudstone	Dark-grey, aphanitic				Bedding at 50^{o} TCA
				70									
37	8	7.5	94	3215-322									
								Siltstone	Medium-dark grey				
					325								Bedding at 50^{o} TCA
													Jointing random, planar
								Mudstone	Medium-dark grey, broken, sphanitic				
38	8	8.9	111		330			Mudstone	Dark-grey, competent, aphanitic				Bedding at 70^{o} TCA
				71									
				3322-333				Siltstone	Medium-dark grey, clayey				Jointing random, planar slick
					335								
								Mudstone	Medium-grey, aphanitic				Bedding at 60^{o} TCA
								Siltstone	Medium-grey, banding near bottom				
39	9	8.5	93	72									
				338-339.5	340								
								Sandstone	Medium grey-competent massive				
					345								

Drilling Rig ____ Hole Diameter ____
Drill Method ____ Bit used ____
Down hole surveys Type
✱ point load test

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD
Project Coal Valley, Pit 13

Corehole Log

Location N 39827 E78218

GEOTECHNICAL SERVICES
Elev. 7441
Dip
Bearing

Hole No CH2193
Date July 7, 1979
Page 10 of 10

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					345								
40	7	7	100					Siltstone	Dark-grey, chloritic				Jointing 11 TCA
					350			Mudstone	Dark grey, broken, aphanitic				
TOTAL			93										
								Sandstone	Medium-grey, medium-grained, Competent				Bedding at 65°TCA
					355				Foot of Hole 354				

Drilling Rig
Hole Diameter
Drill Method
Bit used
Logged by

Down hole surveys
Type

* point load test

Water
II, APRIL 79 WATER LEVEL
WATER INFLOW
WATER LOSS

Strength (indirect tensile strength)
EL EXTREMELY LOW
VL VERY LOW
L LOW
M MEDIUM
H HIGH
VH VERY HIGH EH EXTREMELY HIGH

Weathering
FR FRESH
SW SLIGHTLY WEATHERED
MW MODERATELY WEATHERED
HW HIGHLY WEATHERED
EW EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Hole No CH2194

Project Coal Valley, Pit 13 Location N 39865 E79200 Elev. 4676 Dip Bearing Date July 7, 1979 Page 1 of 9

Run No	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					50				Brown sandstone				
					55								
1	8	7.9	99					Mudstone	Dark grey, aphanitic, badly broken				
									along bedding planes				
													Bedding TCA
					60								
2	9	8.9	99										
					65			Mudstone	Dark-grey, silty, very badly				
									broken TCA				
									poorly consolidated				
					70								
								Sandstone	Light grey, fine grained				Bedding at 85° TCA
3	7	5.9	84					Sandstone	Light grey, fine - medium grained				
				73									
				74.5-75.6									
								Siltstone	Light medium grey				
								Mudstone	Medium grey, aphanitic				
					80								
								Mudstone	Medium grey, silty				
								Sandstone	Light grey-brown, very fine grained				Bedding at 70° TCA
					85								

Drilling Rig Failing1250(b) Hole Diameter 5½
Drill Method air-water Bit used Diamond
Logged by D. Broen Checked by CPA

Down hole surveys Type

* point load test

Water: 11 APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW, VL VERY LOW, L LOW, M MEDIUM, H HIGH, VH VERY HIGH, EH EXTREMELY HIGH

Weathering: FR FRESH, SW SLIGHTLY WEATHERED, MW MODERATELY WEATHERED, HW HIGHLY WEATHERED, EW EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Project Coal Valley, Pit 13 Location N 39865 E79200 Elev. 4676 Dip Bearing

Hole No CH2194 Date July 8, 1979 Page 2 of 9

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					85								
								Siltstone	Medium grey, sandy				
													Bedding at 60° TCA
5	5	3.2	64					Siltstone	Medium grey				
					90			Mudstone	Medium grey, silty iron staining				
6	9	9.1	101					Siltstone	Medium grey, competent				Jointing at 45° TCA
					95								
								Sandstone	Light grey, very fine grained				
													Bedding at 60° TCA
					100								
								Mudstone	Light grey, silty - competent				
				74									Jointing random irregular
7	8	8.1	101	101.6-10									
								Mudstone	Dark grey, silty, carboniterous aphanitic				
					105								
													Bedding at 55° TCA
					110								
8	8	8.0	100					Siltstone	Light green - sandy, calcite infillings				Jointing random
								Sandstone	Light grey, very fine grained calcite infillings				Bedding at 65° TCA
				75	115								
				115-115.8				Siltstone	Medium grey, sandy, calcite veins				Jointing at 35° TCA
								Mudstone	Medium grey, aphanitic				
9	7	6.5	93					Mudstone	Medium dark grey, aphanitic				Bedding 80° TCA
					120								

Drilling Rig ______ Hole Diameter ______

Drill Method ______ Bit used ______

Logged by

Down hole surveys

Type

* point load test

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Project Coal Valley, Pit 13 Location N39865 E79200 Elev. 4676 Dip Bearing

Hole No CH2194 Date July 8, 1979 Page 3 of 9

Run No	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					120								
								Siltstone	Medium-light grey, sandy				
													Bedding at 50° TCA
10	9	8.0	89		125			Siltstone	Medium grey				
								Mudstone	Medium-dark grey, broken, silty,				Jointing at 30° TCA
					130			Mudstone	Dk. grey aphanitic				
11	8	8.0	100	Samp.76	135								
				134-135.5									
								Mudstone	Dk. grey - med. silty				Jointing 70° TCA
								Siltstone	Med. grey - clayey				
					140								
12	8	8.0	100					Mudstone	Dk. grey carbonaceous aphanitic				Jointing 45° TCA
				Samp.77				Mudstone	Med. grey silty competent				
				145-145.8	145								
								Siltstone	Med. grey				
								Mudstone	Med. - dk. grey aphanitic				
								Siltstone	Med. - lt. grey				Bedding 60° TCA
					150								
13	8	6.8	85										
								Mudstone	Dk. grey - med. grey				
									iron filling in veins bright red				Jointing random, planar
					155								

Drilling Rig ______ Hole Diameter ______ Down hole surveys Type

Drill Method ______ Bit used ______

* point load test

Water: ▼ 11, APRIL 79 WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW, VL VERY LOW, L LOW, M MEDIUM, H HIGH, VH VERY HIGH, EH EXTREMELY HIGH

Weathering: FR FRESH, SW SLIGHTLY WEATHERED, MW MODERATELY WEATHERED, HW HIGHLY WEATHERED, EW EXTREMELY WEATHERED

LUSCAR LTD

Project Coal Valley Pit 13

Corehole Log

Location N 39865 E 79200

GEOTECHNICAL SERVICES

Elev. 4676 Dip Bearing

Hole No CH 2194

Date July 8/79 Page 4 of 9

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m	Graphic Log	Water	Rock Type	color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
				Samp. 78	155								
				154.9-157									
14	8	9.0	112					Sandstone	Med. grey fine grained competent				
								Siltstone	Med. grey				Bedding 60° TCA
					160			Mudstone	Med. grey, silty				
								Siltstone	Med. grey				
								Mudstone	Med. grey, silty				Jointing 45° TCA Planar, slick
													Bedding 70° TCA
								Sandstone	Med. grey fine - med. grained				
									massive				
					165								
15	8	8.5	106										Bedding 65° TCA
								Mudstone	Dk. grey aphanitic				
									competent				
					170								
													Bedding 70° TCA
				Samp. 79									
16	8	7.9	99	173.4-17[illegible]									
					175			Mudstone	Med. grey - dk. grey aphanitic				Jointing random, frequent - some slick
									some shearing				
									some banding				Bedding 80° TCA
				Samp. 80									
				177.9-17[illegible]	180								
								Mudstone	Med. grey - green chloritic				
									silty				
17	8	7.0	88										
								Mudstone	Med. dk. grey silty				Jointing random
					185								
								Siltstone	Med. grey competent				
								Mudstone	Med. grey aphanitic				
					190								

Drilling Rig Hole Diameter

Drill Method Bit used

Logged by

Down hole surveys Type

✱ point load test

Water
11, APRIL 79 WATER LEVEL
WATER INFLOW
WATER LOSS

Strength (indirect tensile strength)
EL EXTREMELY LOW
VL VERY LOW
L LOW
M MEDIUM
H HIGH
VH VERY HIGH EH EXTREMELY HIGH

Weathering
FR FRESH
SW SLIGHTLY WEATHERED
MW MODERATELY WEATHERED
HW HIGHLY WEATHERED
EW EXTREMELY WEATHERED

LUSCAR LTD — **Corehole Log** — GEOTECHNICAL SERVICES — Hole No CH2194

Project Coal Valley, Pit 13 Location N 39865 E79200 Elev. 4676 Dip ______ Bearing ______ Date July 8, 1979 Page 5 of 9

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft or m	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
18	8	7.9	99		190			Siltatone	Medium grey, competent				
				81 193-194.1									
					195			Mudstone	Medium grey, silty				Jointing TCA
								Siltstone	Medium grey, sandy				
19	8	6.5	81										
					200								
								Mudstone	Medium grey, silty				
								Siltstone Mudstone	Medium grey, competent				Joint at 45° TCA Straitions
					205								
20	9	9.2	102					Mudstone	Dark grey, aphanitic, broken				
								Siltstone	Dark grey, calcite veining very frequent				Bedding at 65° TCA
								Siltstone	Medium dark grey				Jointing at 30° TCA Planar
					210								
								Mudstone	Dark grey, aphanitic				
									Competent				
21	8	7.5	94		215			Mudstone	Dark grey, broken				
									aphanitic				
								Mudstone	Medium dark grey, silty				
					220			Mudstone	black dull carbanaceous				
								Mudatone	Medium grey aphanitic				
22	8	7.2	90					Siltstone	Medium grey, calcite infilling				
					225								

Drilling Rig ______ Hole Diameter ______
Drill Method ______ Bit used ______

Down hole surveys
Type

* point load test

Water: WATER LEVEL; WATER INFLOW; WATER LOSS

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM; H HIGH; VH VERY HIGH; EH EXTREMELY HIGH

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED; EW EXTREMELY WEATHERED

LUSCAR LTD

Corehole Log

GEOTECHNICAL SERVICES

Hole No CH2194

Project Coal Valley, Pit 13 Location N39865 E79200 Elev. 4676 Dip ______ Bearing ______ Date July 9, 1979 Page 6 of 9

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m	Graphic Log	Water	Lithological Description: Rock Type	color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					225								
				82									
				227.8-228.6	230			Siltatone	Medium grey-brown				
													Calcite vein ½" thick trending 10° TCA
23	8	8.0	100					Siltatone	Medium grey, aandy				Bedding at 55° TCA
								Sandstone	Medium grey, fine grained				Bedding at 55° TCA
					235			Siltstone	Medium grey				
								Mudstone	Medium dark grey, aphanitic				
				83					competent				
				237.6-239									
24	9	9.7	108		240			Siltstone	Medium grey				
								Sandstone	Light grey, very fine grained				Bedding at 50° TCA
									Some calcite veins				
					245								
				84									
25	6	5.6	110	247.1-248				Sandstone	Medium grey, fine grained				Bedding at 40° TCA
								Siltstone	Medium grey, sandy				
					250								Bedding at 40° TCA
								Sandstone	Medium light grey, medium grained				
								Mudstone	Medium grey-green chloritic broken				
								Coal Stringer	3" thick, badly fractured				
26	9	8.2	91		255								
								Mudstone	grey - green, silty				Jointing at 60° TCA Planar
					260								

Drilling Rig ______ Hole Diameter ______
Drill Method ______ Bit used ______
Logged by

Down hole surveys
Type

✱ point load test

Water
▼ 11, APRIL 79 WATER LEVEL
WATER INFLOW
WATER LOSS

Strength (indirect tensile strength)
EL EXTREMELY LOW
VL VERY LOW
L LOW
M MEDIUM
H HIGH
VH VERY HIGH EH EXTREMELY HIGH

Weathering
FR FRESH
SW SLIGHTLY WEATHERED
MW MODERATELY WEATHERED
HW HIGHLY WEATHERED
EW EXTREMELY WEATHERED

LUSCAR LTD — **Corehole Log** — GEOTECHNICAL SERVICES

Project: Coal Valley, Pit 13 Location: N39865 E79200 Elev. Dip Bearing

Hole No: CH2194 Date: July 9, 1979 Page 7 of 9

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Rock Type	color, grain size, bedding, structure, minor components	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					260			
				85				
				2615-2629				
27	8	7.3	91			Siltstone	Medium grey, sandy	Jointing at 70° TCA Planar
					265	Sandstone	Light grey, medium grained	Bedding at 50° TCA
						Siltstone	Medium grey	Bedding at 55° TCA
						Mudstone	Medium grey, silty	
						Siltstone		
						Sandstone	Medium grey, fine grained	
						Siltstone	Medium grey	
					270	Mudstone	Dark grey, carbonaceous	
28	8	5.9	74			Sandstone	Green - fine grained	
						Mudstone	Medium grey - green, silty	
					275	Mudstone	Dark grey, carbonaceous	
						Mudstone	Medium grey - green	Random jointing slick
29	7	7.4	106		280	Mudstone	Medium grey, aphanitic broken	
						Siltstone	Medium grey	Bedding at 60° TCA
					285	Mudstone	Medium grey, aphanitic broken	Heavily fractured - random slick
30	9	5.5	61					
						Mudstone	Medium grey, aphanitic	
					290	Clay	Bentonitic	3" thick
						Siltstone	Medium dark grey	
				86				
				293-294				

Drilling Rig Hole Diameter Down hole surveys

Drill Method Bit used

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW, VL VERY LOW, L LOW, M MEDIUM

Weathering: FR FRESH, SW SLIGHTLY WEATHERED, MW MODERATELY WEATHERED, HW HIGHLY WEATHERED

LUSCAR LTD **Corehole Log** GEOTECHNICAL SERVICES Hole No CH2194

Project Coal Valley, Pit 13 Location N 39865 E79200 Elev. ______ Dip ______ Bearing ______ Date July 9, 1979 Page 8 of 9

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
31	8	10	125		295			Siltstone	Medium grey, competent				
								Mudstone	Medium grey, silty				Stuck in core barrel - fractured vertically
					300								
32	8	5.3	66					Sandstone	Medium grey, fine grained				Bedding at 60° TCA
					305								
								Siltstone	Medium grey, calcite veins				Bedding at 60° TCA
				87									
				307.5-308.5									
					310			Sandstone	Light grey, fine grained, competent				Bedding at 60° TCA
33	4	5.1	128										
					315								
34	8	7.2	90					Sandstone	Medium grey, medium grained, competent				Bedding at 64° TCA
				88									
				318.3-319.3	320			Mudstone	Medium grey aphanitic				
								Siltstone	Medium grey, sandy, competent				
35	8	8.1	101					Siltstone	Medium grey, samdy				Jointing at 55° TCA Planar
					325			Mudstone	Medium dark grey, silty				
									Competent				
								Siltstone	Medium grey				Jointing TCA

Drilling Rig ______ Hole Diameter ______ Down hole surveys

Drill Method ______ Bit used ______

Driller ______ Logged by ______ Type

Water: 11, APRIL 79 WATER LEVEL; WATER INFLOW

Strength (indirect tensile strength): EL EXTREMELY LOW; VL VERY LOW; L LOW; M MEDIUM

Weathering: FR FRESH; SW SLIGHTLY WEATHERED; MW MODERATELY WEATHERED; HW HIGHLY WEATHERED

* point load test

LOSCAR LTD.

Geotechnical Services

Corehole Log

Project Coal Valley, Pit 13 | Location N 39865 E79200 | Elev. 4676 | Dip | Bearing

Hole No. CH2194 | Page 9 of 9 | Date July 9, 1979

Run No.	Length of run	Footage recovered	% recovery	Samples Tests	Depth in ft. or m.	Graphic Log	Water	Rock Type	Lithological Description: color, grain size, bedding, structure, minor components	Weathering	Strength or RQD	Defect Spacing mm	Rock Mass Defects: type, inclination, planarity, roughness, coating, thickness
					330								
36	8	8.2	103					Siltstone	Medium grey, competent				Bedding at 55° TCA
								Mudstone	Medium grey, silty Competent				
					335								
37	9	8.5	94					Mudstone	Medium grey, aphanitic				Bedding at 60° TCA
					340								
								Siltstone	Medium grey				
TOTAL			93					Mudstone	Medium grey, aphanitic, broken				Bedding at 70° TCA
								Siltstone	Medium grey				
					345			Mudstone	Medium grey, aphanitic				
				89 346.5-347.3									
									Foot of Hole				
					350								
					355								
					360								
					365								

Hole Length | Bit used | Down hole surveys

WATER LEVEL | WATER INFLOW